BEHAVIORAL AND POLICY FACTORS INFLUENCING OBESITY IN SOUTH KOREA

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BEHAVIORAL AND POLICY FACTORS INFLUENCING OBESITY IN SOUTH KOREA

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Health officials, scientists, and the public are increasingly concerned about the overweight and obesity epidemics and their negative consequences. While the effects of both individual and policy factors on overweight and obesity are far-reaching, they are poorly understood. Overweight and obesity have become a major public health problem in South Korea, along with its rapid economic growth and globalization process which are related to obesity-related diets and behaviors. The nationwide Korea Health and Nutrition Survey, conducted in 1998 and 2001, and time series data, such as those on imports and prices from around 1970 to the present, were used to address the study objectives. The overall aim of this dissertation was to investigate behavioral and policy factors related to obesity. Effects of price, income, community characteristics, dietary intake, and physical activity on waist-hip ratio were thus investigated in South Koreans. Under the assumption that the effects of trade were mediated through prices and income, the possible linkage between trade liberalization and obesity was also studied. The specific research questions are as follows: how do dietary intake, physical exercise, prices, income, and national health policies affect obesity in South Korea?; which factors among dietary intake, physical exercise, prices, income, and national health policies are relatively more important for obesity programs and policies

for Koreans?; and, What are the magnitudes of price effects in terms of waist-hip ratio? Based on an econometric modeling, I found, first, individual, household, and community characteristics were associated with central obesity in South Koreans. Prices had an influence not only on dietary intake but also on physical exercise. Second, effects of income were mediated through dietary intake. Dietary intake, physical exercise, prices, and receiving health examinations were important factors for the prevention of central obesity. Third, price had a direct impact on obesity. When prices decreased by 10%, the prevalence of overweight increased about 2% in the studied population. Community income levels seem to be more important than individual income levels in obesity in Koreans. Although it is difficult to detect the association between trade and obesity, there might be relations between trade and obesity under the assumption that its effects are mediated through prices and income in this study. Whether effects of governmental health policy such as receiving health examinations might be preventive against obesity needs to be studied in a follow-up study. Not only individual behavioral factors but also policy factors are important in the reduction and prevention of obesity. To reduce and prevent obesity, it is important to find an appropriate target population. This study would be helpful for the targeting in Koreans.

BIOGRAPHICAL SKETCH

Ji-Yun Hwang was born and brought up in South Korea. She is the eldest daughter of Ho Yeon Hwang and Hey Sook Park. She did her B.Sc. and M.S. from Ewha Woman's University, majoring in Food and Nutrition in 1998. She is also a registered dietitian in Korea. The topic was her master's thesis was about health and nutritional status of North Korean in South Korea. She worked in Korean National Institute of Health (KNIH), as a researcher for 1 year. She continued her affiliation with the KNIH until 2008. Her work consisted of investigating the relations between socioeconomic status and health, such as age at menarche, depression, and obesity. In 2001, she started her Ph.D study in the field of International Nutrition at the Division of Nutritional Sciences at Cornell University. She has minored in the fields of Epidemiology and Economics. Much of her research focuses on economic factors in relation to nutritional status. This work is Ji-Yun's autobiography.

To my mother

Hey Sook Park

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CHAPTER 1
INTRODUCTION

This chapter begins with an overview of the history of obesity research. A brief description of effects of economic development and globalization on obesity is also presented. There is discussion of the importance of studying the determinants of obesity. Next, the globalization and overweight and obesity and the effect in South Korea are described. This is followed by a description of this study's conceptual framework containing multi-dimensional aspects of determinants of overweight and obesity. Research goals and questions and the relevance of the research are discussed.

1.1. Historical perspective on research about overweight and obesity

The history of the scientific study of overweight and obesity began in 1773. Lavoisier found that the heat of a guinea pig derived from chemical processes was identical to that derived from a piece of burning wood, showing the chemical identity of combustion and respiration. Since then, scientists have discovered the principles of thermodynamics and their applicability to biological systems (Kleiber 1975). Mayer (1953; 1955) proposed that the central nervous system sensed glucose and regulated energy intake by a glucostatic system. Kennedy (1953) hypothesized a lipostatic system whereby body fat stores produced a signal that affected energy homeostasis. Meyer and Hargus (1959) proposed an aminostatic system whereby the quality and quantity of amino acids ingested affected energy homeostasis.

A body of evidence has shown that body weight is regulated by complex signaling systems that provide afferent signals (including glucostatic, lipostatic, and aminostatic signals) to the central nervous system about the nutritional state of the organisms; these are translated into efferent signals that affect energy intake and expenditure (Keesey 1989). Research in molecular physiology has been discovering the physiological targets of weight regulation in human obesity (Rosenbaum, Leibel, Hirsch 1997; Leibel, Chung, Chuo 1997). However, the precise etiology remains unknown (Rosenbaum, Leibel 1998). The recent development of molecular biology encourages investigators to conduct genetic studies of which genes are relevant to the phenotype susceptible to obesity. Individual characteristics are also important since what causes the imbalance between calorie intake and output may vary from one person to another. For instance, individual knowledge and education could modify the effects of determinants on outcomes.

Recently, a growing body of evidence shows that environmental determinants may be playing an important role in the obesity epidemic. Studies of twins, adoptees, families, and animal models of obesity indicate that obesity is a result of both genetic and environmental factors (Hager *et al*. 1998; Stunkard *et al*. 1990; Friedman, Halaas 1998). In the U.S., the prevalence of overweight (defined by BMI corrected for age and sex) increased by 40% (Troiano, Flegal 1998; Kuczmarski, Flegal 1994) and the prevalence of obesity by 33% (Kuczmarski, Flegal 1994) just in the ten years between the NHANES II (1976~1980) and III (1988~1991). Thus, the prevalence increased considerably during a period much too short for any significant change to have occurred in the genetic makeup of the population. The observation indicates that non-genetic factors such as massive environmental changes over recent decades, leading to a rise in sedentary pursuits or a decrease in physical activity and an increase in energy or fat intake have played a significant role in the current obesity epidemic. Environmental factors behind overweight and obesity, therefore, should be investigated from a multidisciplinary and dynamic perspective, including concern for nutrition, public health, education, psychology, and economics.

1.2. Effects of economic development and globalization on overweight and obesity

Environmental influences on overweight and obesity are primarily related to dietary intake and physical activity behaviors. Economic development and concurrent globalization are likely to influence the obesity epidemic through changes in income, prices, and social structures. Under globalization, the saying, "we sink or swim together," refers to international economic relations (Oxfam International 2002).

Economic development and industrialization have changed dietary intake and physical activity in ways that contribute to weight gain by reducing food prices, increasing food availability and decreasing physical activity by shifting energy exertion from human power to machine power. For the reason, people in economically developed countries are more likely to be overweight or obese than those in developing ones (Sobal, Stunkard 1989; Sobal 1999a). Thus, overweight and obesity were thought to be problems mainly in the developed world before we found the so-called nutrition transition problem due to economic growth and globalization in the developing world.

Developing countries have experienced rapid changes in diets and activities with the globalization process. The incidence of overweight and obesity is increasing and often growing faster in many developing nations, even in countries where hunger persists (Babinard, Pinstrup-Andersen 2001;WHO 2003). A higher prevalence of obesity was found in men whose mothers experienced food deprivation during pregnancy (Barker 1994). Children with low birth weight are more likely to develop abdominal obesity and other diseases related to Syndrome X during adulthood. Trade liberalization of food markets has brought changes in food intake, the composition of diets, and the flow of Western diets during the last decades. Increased trade accelerates a major shift in the structures of diets: traditionally high-priced diets, rich in sugars, oils, and animal fats has become low-priced and can be substituted for conventionally low-priced diets, rich in fiber and grain, that have become relatively high-priced (Diza-Bonilla *et al*. 2002). Changes in dietary intake that have taken place across more than a hundred years in Western countries occur within a few decades in the developing countries (Popkin 2002; Phillips 1993). Simultaneously, activity changes have been as fast as dietary changes (Popkin 2001). Diminished physical activity has contributed to a long-term trend of increasing body size due to automated transport, urbanization, technology at home, changes in occupational structure, and more passive leisure pursuits (WHO 2003).

Separating out globalization as a cause of nutritional outcomes is difficult when there are many other factors involved (Pinstrup-Andersen 2002). For example, in the case of overweight and obesity, the effects of other factors, such as macroeconomic policies (e.g., financial or trade liberalization), social policies (e.g., national health policy), price and income changes, urbanization, and occupational structures mediate the effects of globalization, and they strengthen or offset each other. Hence, plans to prevent overweight and obesity involve policies in the areas of public health, finance, agriculture, manufacturing, transportation, and education (Cannon 2001).

The phenomena of overweight and obesity in developing countries are more complicated and somewhat different than in developed ones. The speed of the transition and the factors influencing it vary from country to country and, within a country, between various subgroups (Popkin 2002). As regards income, energy and fat intake have been increasing as income increases in some developing countries (Kim, Moon, Popkin 2000; Matsumura 2001; Uauy, Albala, Kain 2001; Lee, Popkin, Kim 2002) whereas the opposite pattern is typical in developed ones, perhaps due to the lack of a stigma attached to overweight and obesity in most developing nations. Thus, the mechanisms and major determinants should be investigated with consideration given to these complexities in order to reverse or prevent the obesity epidemic.

The problem must also be seen within the context of each society. Each society has its own values for how people interpret their own body weights and those of others (Sobal 2002). Overweight or obese African women have been viewed as healthy, fertile, and financially secure. In Europe and the U.S. before 1900, plumpness was valued as insurance against consumptive illness (Stearns 1997). As body weights increased in most societies during the second half of the twentieth century (Seidell 1995; Kusczmarski *et al*. 1994; Flegal *et al*. 1998; Harlan *et al*. 1988), slimness for women has increasingly valued as the ideal (Garner *et al*. 1980; Wiseman *et al*. 1992). As societies have moved through time, clear shifts have occurred both in body size and values about plumpness (Sobal 2002). That is, when the majority of the world was worried about food, fatness was a symbol of well-being (Sobal 2002). After some parts of world achieved economic growth, however, social rejection of fatness increased. Cross-cultural analyses suggest that most cultures in the world have valued moderate fatness and avoided extreme thinness (Brown, Connor 1987; Anderson *et al*. 1992).

1.3. The importance of understanding determinants of overweight and obesity

Health officials, scientists, and the public are increasingly concerned about the obesity epidemic and its negative consequences. The term "globesity" refers to the increasing global epidemic of obesity. Obesity is now one of the major global burdens among diseases. Worldwide, over one billion adults are overweight and at least 300 millions of them are clinically obese (WHO 2003). The obesity epidemic is not limited to developed countries; it is often growing faster in developing nations (WHO 2003). The world health problem has been characterized as fighting the "double burden" of diseases (WHO 1998): a burden of preventable mortality and disability mostly due to infectious diseases, malnutrition, and complications of childbirth; and non-communicable diseases (NCDs) due to the increased life expectancy with changes in lifestyle from socioeconomic progress.

It is known that overweight and obesity bring huge costs in terms of health consequences and monetary costs. Obesity is a major determinant of many chronic degenerative diseases such as coronary heart disease (CHD), diabetes mellitus, and stroke (WHO 1997). In the U.S., the costs of mortality and morbidity from cardiovascular disease (CVD), cancer, gallbladder disease, diabetes mellitus, and musculo-skeletal disorders were estimated at about US$69 billion per year in 1994 (Wolf, Colditz 1994) and are expected to be much higher now. The real costs of obesity and its co-morbidities in Asia and the Pacific have not been evaluated in any detail (WPRO 2000). Obesity has become a major public health problem in South Korea, with its rapid economic growth and globalization process that have induced an obesity-related diet and behaviors. Now, obesity-related diseases such as CHD and stroke are major causes of mortality in South Korea.

The results of this study conducted in South Korea should therefore be useful for clinical settings, academic research, and the policy-making process in the current obesity epidemic. Finding the best and most cost-effective indicators for defining obesity could contribute to accurate targeting of individuals who are or are likely to be obese. Evidence of the impact of food insecurity on children, women, and men living in Korea would be important for supporting new policy and program initiatives designed to alleviate food insecurity. To fully benefit from the globalization process, it is important for developing nations to know its positive and negative aspects. To understand the effects of globalization on obesity under the conditions of a nutrition transition economy such as that in Korea would be useful to them for emphasizing the positive aspects of globalization and preventing its negative ones.

1.3. Globalization and prevalence of overweight and obesity in South Korea

1.3.1. Globalization process in South Korea

South Korea was a typical Asian agricultural country until the mid-1960s. In the short period from 1970-90, export-led industrialization transformed South Korea from one of the world's poorest economies to the 11th largest and to the world's 13th biggest international trader. South Korea has rapidly experienced globalization and its pressures since the 1990s. It entered into the World Trade Organization (WTO) in 1995, and the

Organization for Economic Co-operation and Development (OECD) in 1996 and it experienced a financial crisis leading to an International Monetary Fund (IMF) loan from December 1997 to 1998. The agreement under the WTO, the terms of Uruguay Round Agreement, on Agriculture and the financial crisis were important moments for Korea's globalization process.

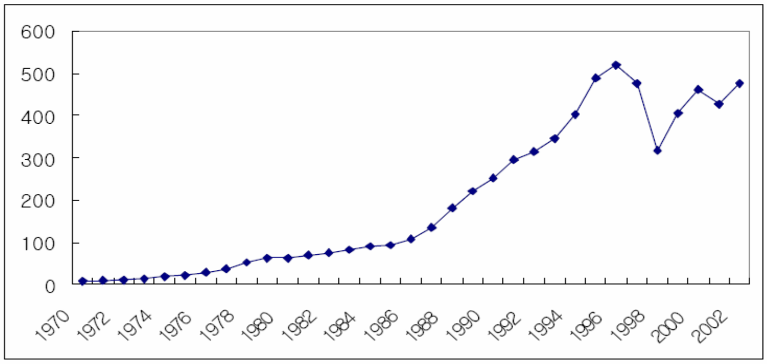
South Korea's gross domestic product (GDP) was U.S. $8 billon in 1970 and rose to U.S. $520 billion in 1996, but went down to U.S. $477 billion in 2002 after its financial crisis in 1997. Its exports increased from U.S. $250 million in 1966 to U.S. $163 billon in 2002. The export-led policy as well as a gradual import liberalization increased trade flows. The ratio of trade to GDP increased from 35% in 1970 to 60% in the early 1980s and has roughly stabilized since then. Import liberalization was greatly affected by the downward trend of the average import tariff rate from 40% in 1970 to less than 10% in the 1990s. As a result, the share of South Korea's exports in world trade increased from 0.3% in 1970 to 2.5% in the 1990s. Foreign direct investment (FDI) flows had been diminutive until the mid-1980s but substantially increased during 1980-1997 more than ten fold. South Korea has been more dependent on trade and foreign investment during the process (Figure 1.1).

Globalization also affects people's knowledge through the development of telecommunications. For example, many people now are getting information simply through the internet. In South Korea, the *kr* (indicating Korea) -domain was 26,166 in 1998 and became 457,450 in 2001, indicating rapid development of internet infrastructure. Information on food and health through the internet, TV, newspapers, and radios is not always true. Most individuals, however, are not able to avoid wrong information.

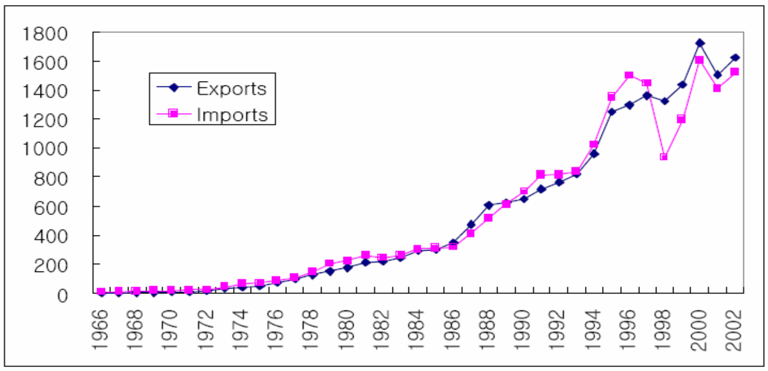
1.3.2. Trade liberalization in foods in South Korea

Since the 1960's, South Korea has been a large net importer of agricultural products. On the basis of the Uruguay Round Agreement in 1995 managed under the WTO, food markets in South Korea were liberalized as follows. Beef was the first meat opened to trade. After a General Agreement on Tariffs and Trade in 1989, Korea committed itself to operating minimum import quotas. Then, after the beginning of 2001, the beef market was fully liberalized. Imports of frozen pork and poultry meat were liberalized from July 1997. Tariffs have been reduced to 25% for pork and 20% for chicken in 2004. The ban on grape imports ended in January 1996. The tariff rate quota on oranges and the import quota on orange juice ended in July 1997. South Korea has dramatically increased its imports of processed agricultural products. U.S. exports more than tripled between 1990 and 1996. They dropped in 1998 due to economic crisis but rebounded in 1999.

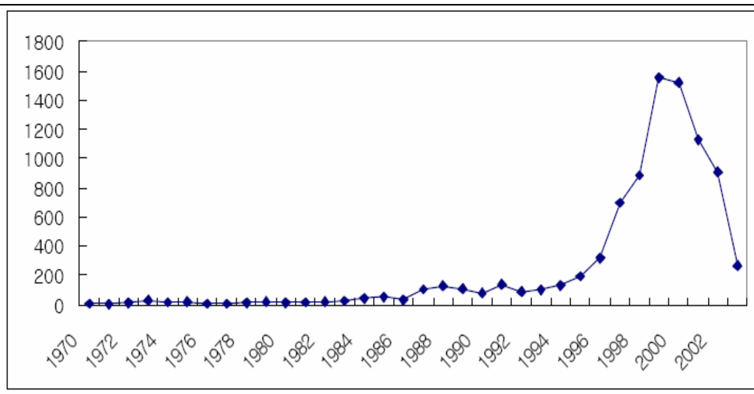
The combined materials of the Korea National Health and Nutrition Surveys (KNHNS) of 1998 and 2001 and national data from 1970 to the present provide the following facts (figure 1.2). First, (a) the price of vegetable oil decreased steeply between the two surveys and consumption has been increasing as well. If people are divided into four groups based on economic status, the richer people are, the more they have consumed vegetable oil. Next, (b) the price of soft drinks has decreased only a little, but the price of sugar has decreased greatly. The intake of soft drinks and sugar went up more among people in rural areas. Moreover, (c) the price of pork and chicken went up across the two survey periods, but consumption went up as well. Finally, (d) for grapes, the price decreased from 1998 to 2001, and the intake increased steeply during the same period. The finding for (c) might be due to the price



b. Gross Domestic Product, 1970-2002 (units: 1 billion U.S. dollars)



a. Exports and imports, 1966-2002 (units: 100 million U.S. dollars)



c. Foreign direct investment, 1970-2002 (units: 10 million U.S. dollars)

Figure 1.1 Secular trend of (a) gross domestic product, (b) exports and imports, and (c) foreign direct investment of South Korea.

Data source: Korean National Statistical Office increase in beef. The price of domestic beef went up 45% (72.1 to 116.9) during the same period (figure 1.3). After liberalization of the beef market in 2001, the price of domestic beef went up and imported beef went down. Daily intake in 2001 reflected these changes by showing that people consumed 23.1g of imported and 2.4g domestic beef daily.

International trade in foods would affect food availability and further food and nutrient consumption. For example, for both North and South Korea, the supply of coffee beans and bananas is totally dependent on imports. The differences between the two countries are due to the degree of openness to international trade in food (figure 1.4). The change in the Korean agro-food sector in response to the trade liberalization brings a great demand for and a supply of food variety and quality. There has been a concern about the rapid increase in the fast food culture with the help of marketing most evidently by transnational corporations, fast food or family restaurant branches, and big supermarket branches.

The global western food system provides volumes of relatively inexpensive energy-dense foods to all people in the world. The lowered market prices changed the peoples' dietary choices from traditional to Western styles. Although it seems to be true that recent weight increases in Koreans are due to trade liberalization such as the flow of inexpensive Western foods, few studies indicate clear evidence. Some previous studies have shown that Korea's economic development, along with globalization, has contributed to increased body size in South Koreans (Kim *et al*. 2000; Popkin 2001). These findings, however, are not adequate evidence, because of lack of: 1) linkages between globalization and individual outcomes; 2) a clear framework of pathways. Global, national, community, household, and

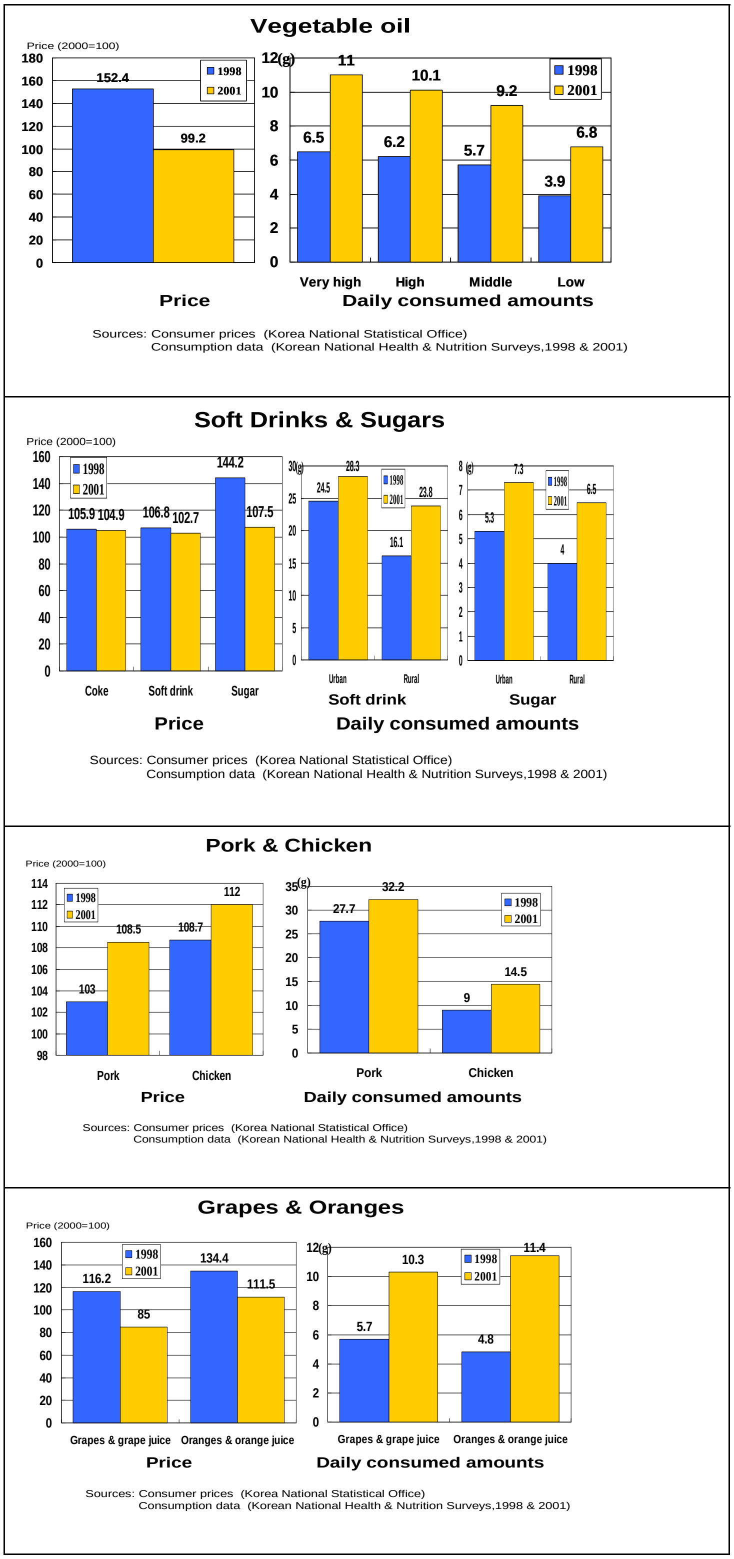
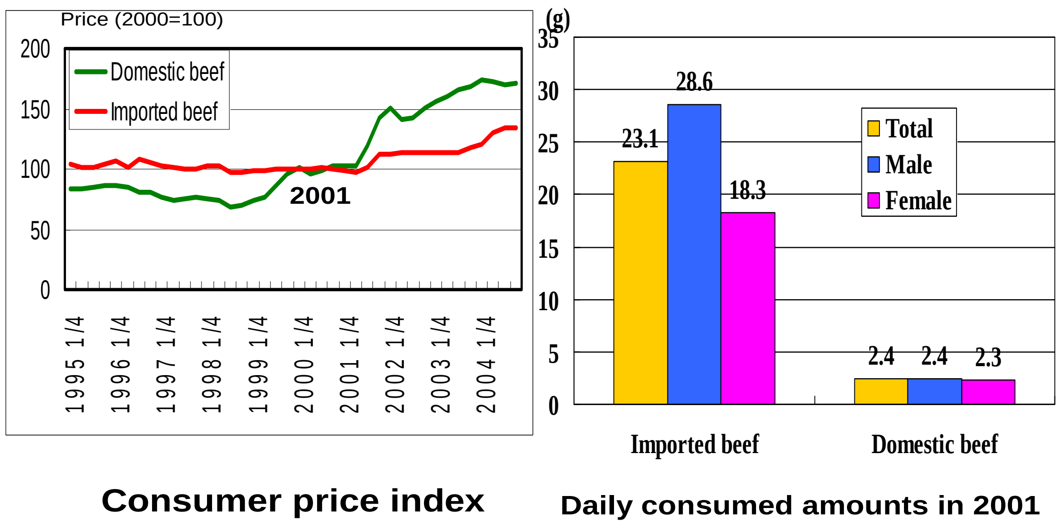


Figure 1.2 Prices and daily consumed amounts of foods between 1998 and 2001

Imported & Domestic Beef



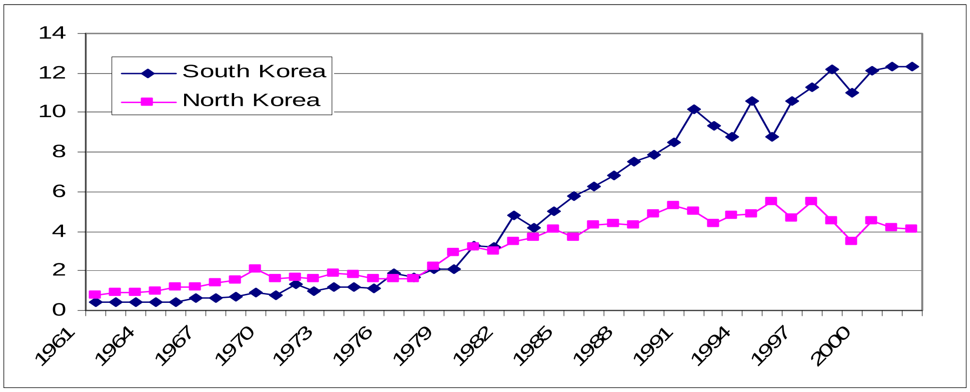
Sources: Consumer prices (Korea National Statistical Office)
Consumption data (Korean National Health & Nutrition Surveys,2001)

Figure 1.3 Prices and daily consumption of imported and domestic beef

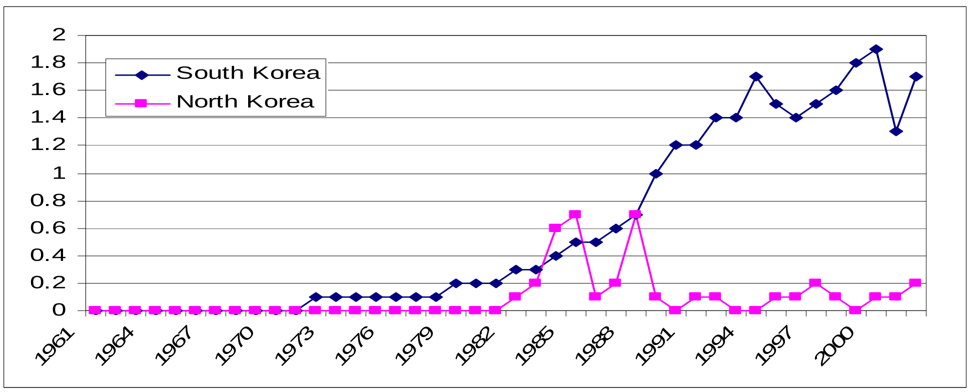
individual level data have been examined in a few previous studies about obesity (Wang 2001). Studies usually mix levels of variables together without thinking about the levels of indicators (Lakdawalla, Philipson 2002; Wang 2001). Since the distances between these indicators and obesity are different, e.g., proximal or distal, the studies are not appropriate for understanding the causes of obesity. In addition, previous studies have not fully considered all the relevant and important factors of obesity.

1.3.3. Overweight and obesity in South Korea

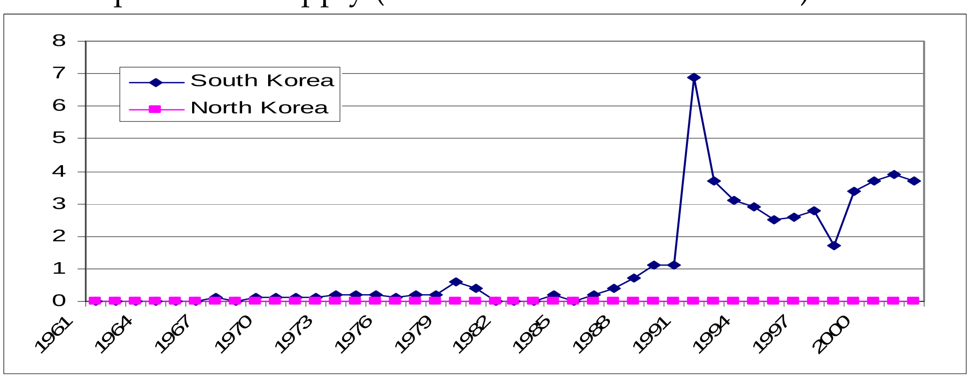
Figure 3.5 shows the mean BMI in Korean population since 1913. Lighter colors for 1995, 1998, 2001, and 2005 show the mean reported in recent KNHN surveys. Until 1995, the trends exhibit fluctuations over time, since height has increased, which reduces the value of the BMI. However, the BMI has gone up continuously since 1995. At the same time, the prevalence of both overweight and obesity has gone up in both males and females (figure 3.6). Koreans suffer from a high level of overweight, although the prevalence of obesity is relatively low. The 2001 survey showed that the overweight among adults was 29.6% for men and 25.9% for women, which translates into an increase of 5.3% for men and 2.4% for women from 1998. The overweight prevalence about doubled in males from 1995 to 2001 and more than doubled in females. Though the prevalence of obesity is relatively low, it has been consistently increasing since 1995. The prevalence of obesity among adults ranged from 2.8 to 3.5% - an increase of less than one percentage point between 1998 and 2001. The Korean Department of Ministry of Health and Welfare defined obesity as BMI≥25 kg/m^2 based on the cutoffs for determining



a. Per capita banana supply (from FAO food balance sheet)



b. Per capita coffee supply (from FAO food balance sheet)



c. Per capita vegetable oil supply (from FAO food balance sheet)

Figure 1.4. Per capita supply of (a) banana, (b) coffee, and (c) vegetable oil in North and South Korea.

Data source: FAO food balance sheet

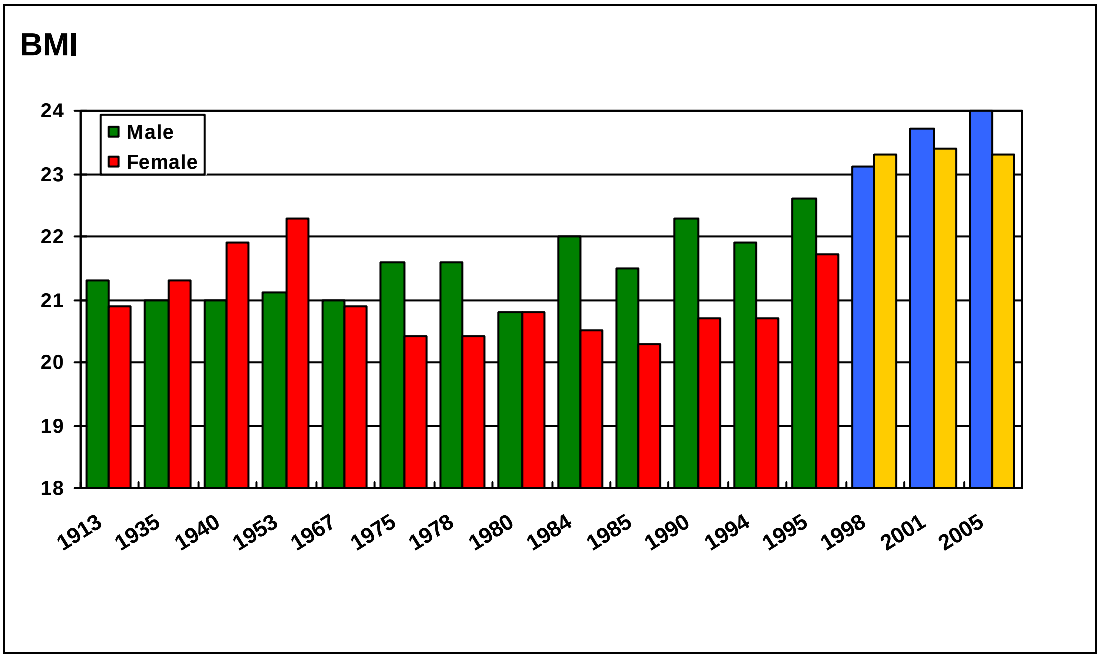


Figure 1.5 Secular trends in BMI Mean in Korea

Data sources: Kubo (1913), Kokida (1935), Lee (1940), Kim (1953), Kwon and Park (1967), Park (1978, 1984), FAO/KA (1980, 1985), KNS (1990, 1994), NNS (1995, 1998, 2001, 2005)

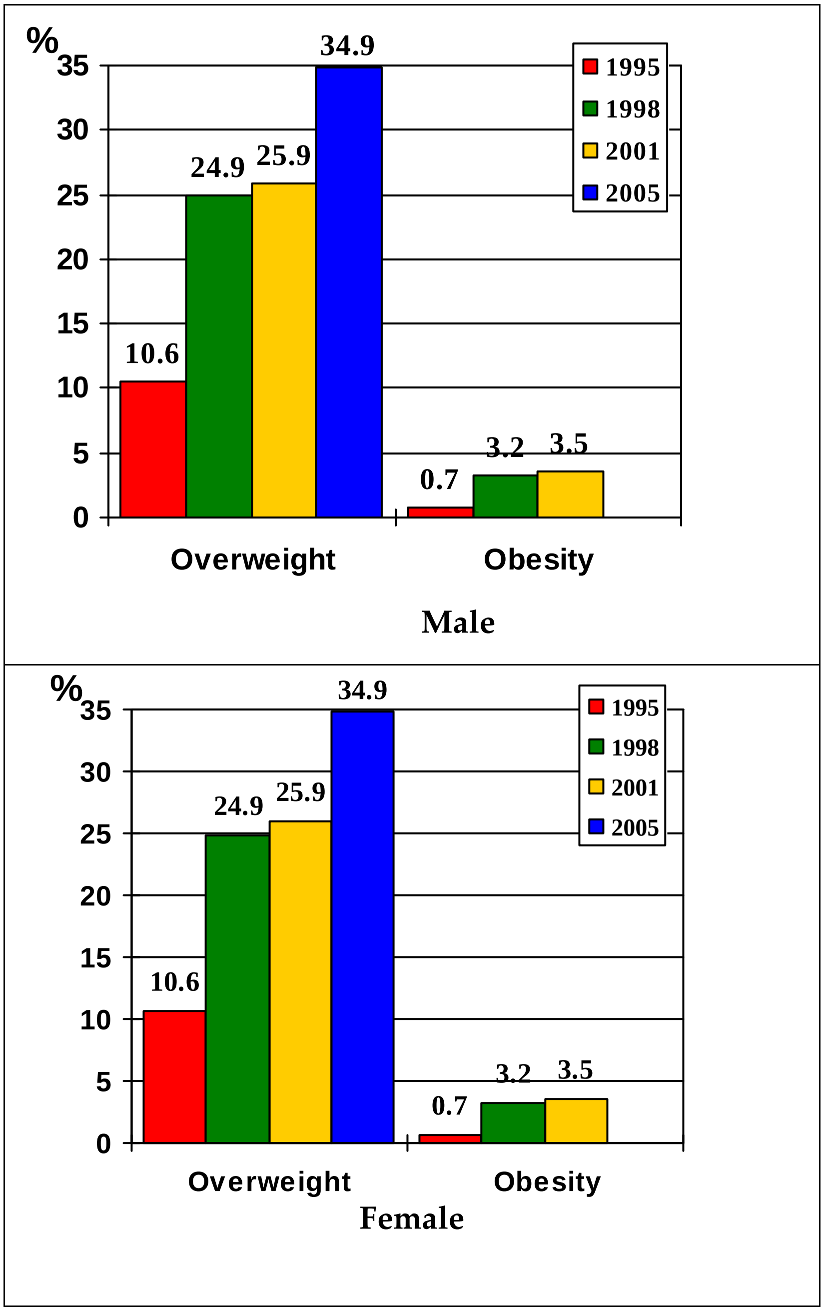


Figure 1.6. Overweight and obesity in Korean adults

Note: Overweight BMI 25-29.9 kg/m^2; Obesity BMI ≥30 kg/m^2

Data sources: Korean National Health and Nutrition Surveys 1995, 1998, 2001, 2005 obesity in Asian populations. In the report of the 2005 KNHN survey, people with BMI over 25 were reported as an obese group. The proportion of people with BMI over 25 has increased by 2.2% in males and 9% in females.

2. Research Questions and Relevance of Research

2.1. Research goal and questions

The overall research goal of the proposed study is to determine the possible linkages between globalization and body measurement: effects of dietary intake, physical activity, income, price, national health policies, and other individual, household, and community characteristics on waist-hip-ratio in adult South Koreans. In particular, I investigate the effects of globalization on overweight and obesity as mediated by prices and incomes. The specific research questions are as follows:

1. How do dietary intake, physical exercise, prices, income, and national health policies affect obesity in South Korea?
2. Which factors among dietary intake, physical exercise, prices, income, and national health policies are relatively more important for obesity programs and policies for Koreans?
3. What are the magnitudes of price effects in terms of dietary intake and waist-hip ratio? Are they consistent with long-term effects? Are changes in food prices related to trade related to changes in prevalence of overweight and/or obesity?

2.2. Relevance research

Although recently the concept that globalization has affected overweight and obesity has received academic attention, the actual pathways through which it could do so have not been fully investigated. Research on such pathways would be important for a number of reasons:

1. Using a very explicit model, this research could identify the pathways through which globalization operates and determine how important it is in explaining overweight and obesity.
2. Such research would make the concept of globalization clearer by viewing two aspects of globalization, i.e., trade liberalization and urbanization as an indirect effect which mediates through other variables rather than constituting a variable with a direct effect on overweight and obesity.

This research can contribute by introducing this new approach and also by providing quantitative evidence for its usefulness.

3. Theoretical Framework

3.1. Main characteristics

The complete conceptual framework for the study is shown in Figure 1. The simplified conceptual framework that will be used for this research is shown in Figure 2. Arrows represent the direct effects. The T-formed lines represent interactions or effect modifications (interactions). The most important characteristics of this framework can be summarized as follows.

1. The framework explicitly identifies the pathways through which different aspects of globalization operate. One problem in the globalization literature is that different aspects of globalization are not specified and individually linked to the outcome variable. Another problem is that many researchers put indicators of

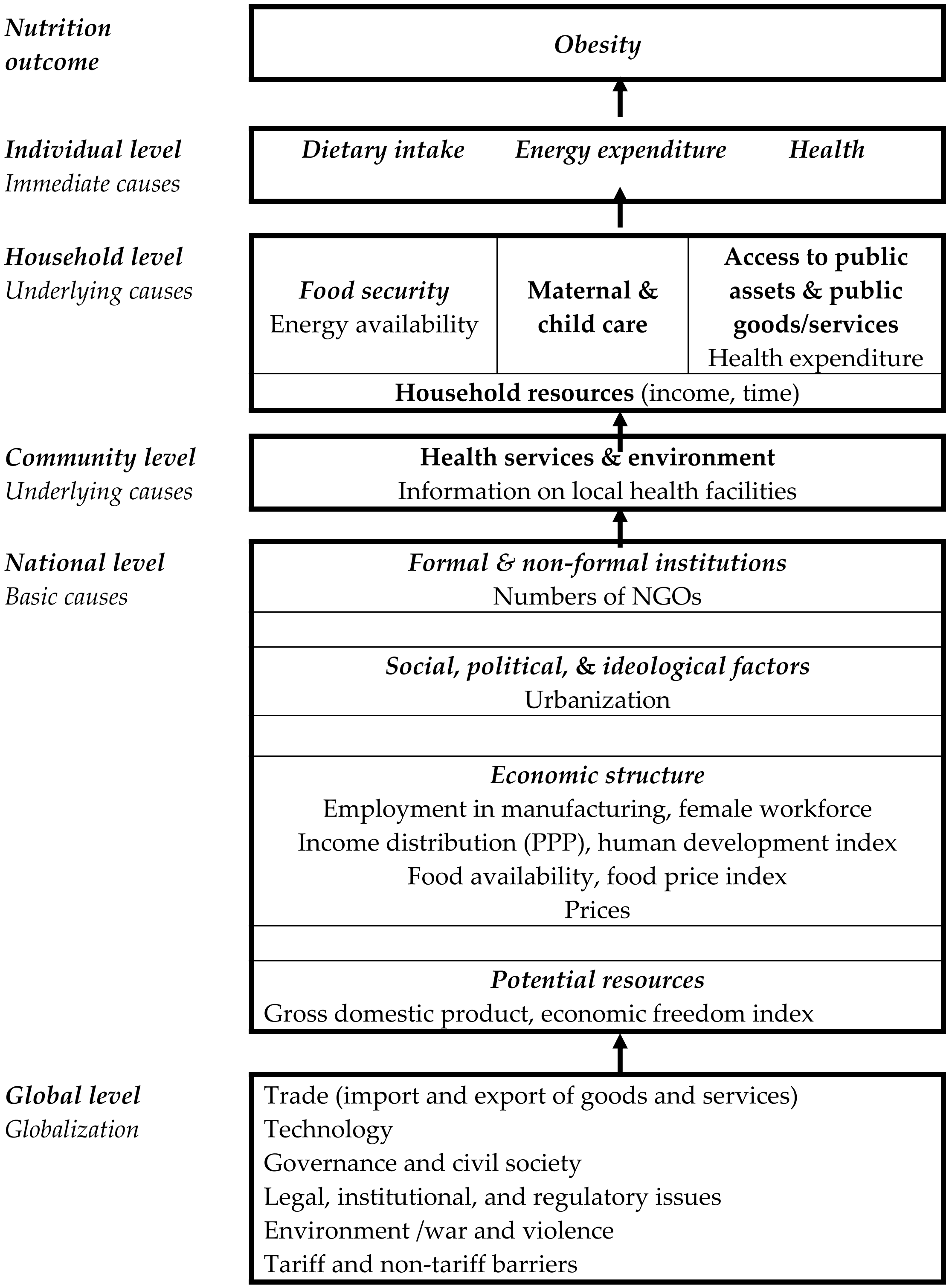


Figure 1.7 Conceptual framework of the study based on UNICEF, 1998 (“Causes of child undernutrition”)

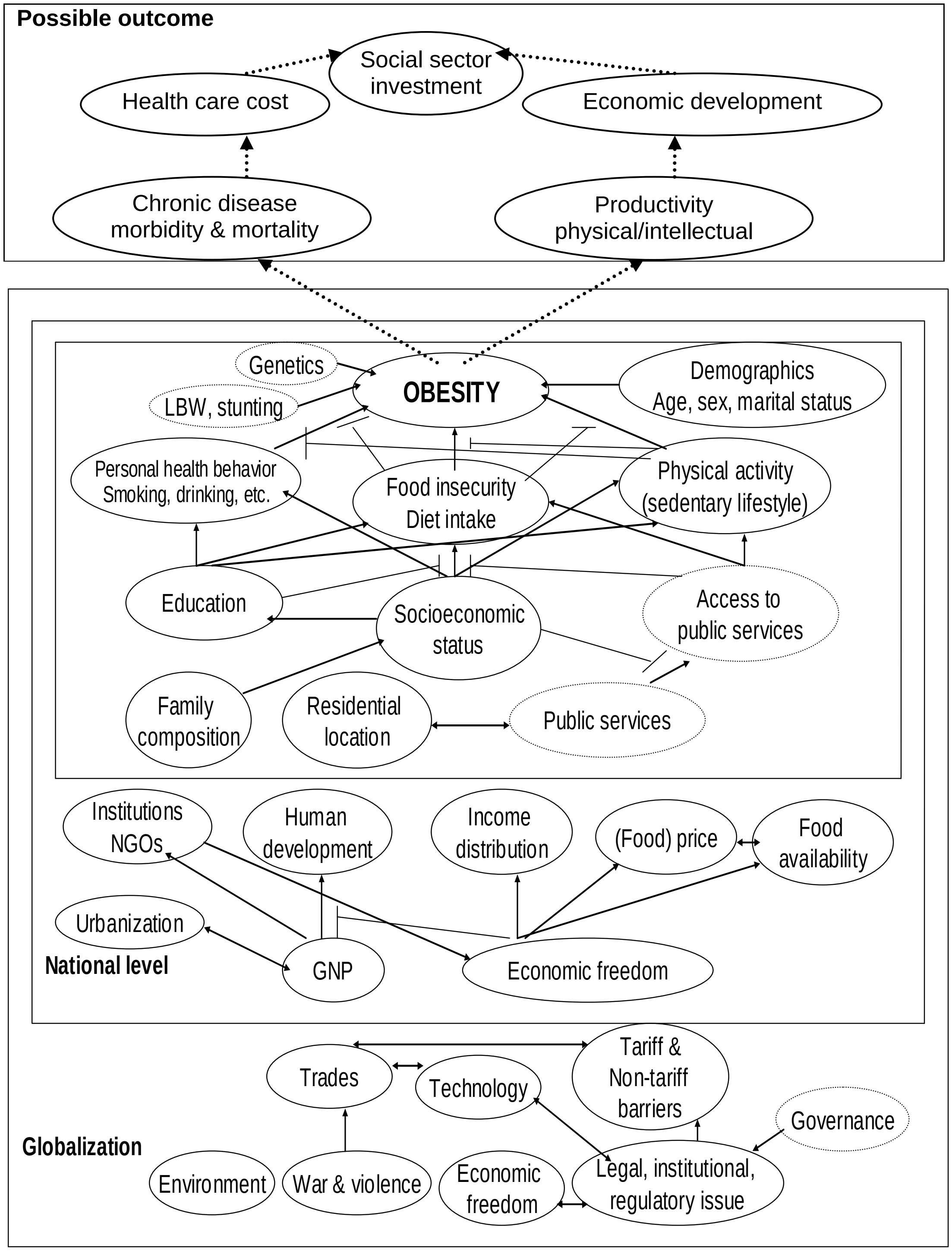


Figure 1.8 The framework of the study

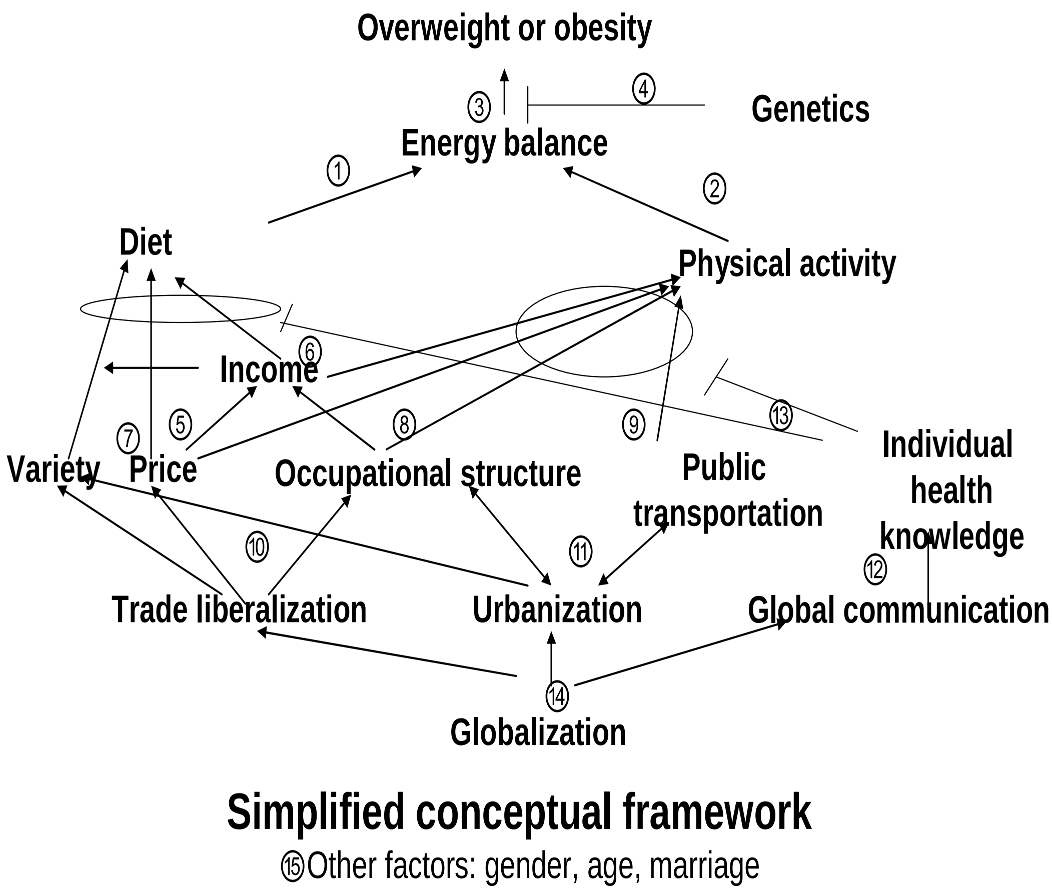


Figure 1.9 Simplified conceptual framework

globalization into the model without thinking through the causal mechanism of the problem.

2. As shown in the framework and research questions, global education in terms of personal knowledge is an effect modifier. Individual knowledge modifies the association between distal and more proximate determinants of overweight and obesity and between the most proximate determinants and overweight and obesity itself. This can also answer recent arguments about the relative importance of environment and education in overweight and obesity research.

The framework in Figure 1.8 depicts the causal relations, both determinants (solid lines) and outcomes (dotted lines) of obesity. Single-headed arrows represent potential causal pathways, and double-headed arrows represent non-causal correlations. Some variables may not be included (dashed circles) due to lack of information. The economic freedom index is derived from 50 independent economic variables which fall into ten broad categories of economic liberalization: trade policy, fiscal burden of government, government intervention in the economy, monetary policy, capital flows and foreign investment, banking and finance, wages and prices, property rights, regulation, and black market activity.

CHAPTER 2

LITERATURE RIVIEW

This chapter starts with the definitions of overweight and obesity. A review of the evidence of the influence of individual, household, community, and national characteristics on overweight and obesity is presented. In what follows, the numbers in Figure 1.9 are used to organize the discussion. Framework 1.9 is discussed in more detail and evidence is given for the relations shown in the framework.

2.1. Definitions

2.1.1. Overweight and obesity

2.1.1.1. Overweight

Overweight is generally defined as weight in excess of some cutoff. It is usually defined as weight over a specific percentage of some standard weight, with standard weight being a function of height. A number of reference standards for weight-for-height are available. There are also several methods for combining weight and height information to produce an index of overweight implicitly related to some standard weight. Identifying overweight individuals is very important because this group of people is the group at risk for obesity.

2.1.1.2. Obesity

Most people think of obesity as being very overweight. Health professionals define overweight as an excess amount of body weight that includes muscle, bone, and water as well as fat. Bray (1978) defined obesity as existing “when fat makes up a greater than ‘normal’ fraction of total body weight”. Obesity refers to an excess amount of body fat. Some people, such as athletes with lots of muscle, can be overweight without being obese. Obesity is body fatness, expressed as a percentage of total body weight above a specified cutoff. Most health care providers agree that men with more than 25 percent body fat and women with more than 30 percent body fat are obese.

2.1.1.3. Difference between overweight and obesity

Overweight and obesity are, thus, conceptually distinct by definition. Overweight is defined as body weight, expressed as a percent of some standard weight, in excess of some cutoff. Obesity is defined as body fat, expressed as a percent of total body weight, in excess of some cutoff. Moreover, overweight and obesity are measured differently. Overweight is a population-based concept, whereas obesity is a physiological concept. The unit of measurement of overweight is the percent of standard weight; hence, overweight cannot be expressed without first defining a population-based standard. The various indices of overweight based on weight and height also rely indirectly on a standard weight. On the other hand, the unit of measurement of obesity is fatness as a percent of total body weight. This can be determined for a single individual without referring to any other standard. Since overweight individuals may not be obese and obese individuals may not be overweight, a measure of overweight may rank individuals differently than a measure of fatness. Thus, the use of overweight as an indicator may misclassify individuals with respect to obesity.

2.1.1.4. Predicting body fatness

Since obesity is body fatness expressed as a percentage of total body weight above some specific cutoff, it should ideally be defined on the basis of body fatness measurement. However, direct measurement of the body fat content of a living person is not possible. A number of indirect methods of measuring fatness have been developed for investigating body composition. As laboratory assessments, there are hydrodensitometry, air displacement plethysmography, isotope dilution, and dual-energy X-ray absorptiometry (Wagner, Heyward 1999). These methods work according to a common principle. Some gross measurement of the body is made, an estimate of the body is made, and an estimate of body fatness is derived from this measurement by reference to a particular model of body composition with some assumed constants. Although these methods stand for a technological advance and are used as the reference standard, they require the use of sophisticated equipment and techniques used only in research centers, which are impractical for use in epidemiological studies. Other advanced laboratory methods such as neutron activation, computed tomography, and magnetic resonance imaging also exist, but they are generally unavailable and very costly (Wagner, Heyward 1999).

For the field, there are simpler methods for estimating body fat: bioelectrical impedance analysis (BIA), near-infrared interactance (NIR), skinfolds, and anthropometry. BIA involves sending a harmless amount of electricity through a person's body. NIR uses two wavelength signals, one at peak and the other at minimum absorption. Skinfolds measure the thickness of the layer of fat just under the skin in several parts of the body. These methods are broadly used, but results from these methods can be inaccurate if done by an inexperienced person or on someone with severe obesity. These methods are generally accepted as the most precise and sophisticated ways to estimate body fatness. It is important to note, however, that all are still indirect methods.

In anthropometric measurement, weight-height functions are generally designed to measure overweight, and it is universal to define overweight as a percentage of standard weight-for-height. In general, the percent of body fat would not be expected to increase linearly with weight relative to height. Furthermore, an index which increased linearly with weight relative to height would not be expected to increase linearly with fatness. Thus, the choice of the weight-height function depends on whether one desires to express deviations from the standard in terms of overweight or in terms of fatness.

The common practice may be described as choosing that integer value of n in an index of the form W/H^n which is closest to the value of n found by other researchers using population-specific linear regressions of weight on height in Western white male populations. In almost every case, this comes down to using the Quetelet index; as James (1976: 4) puts it, "an index such as W/H^2 is the best index of the form W/H^n." There are general criteria for evaluating these indices: the best index is independent of height, highly correlated with weight, and correlated with other measures of adiposity. Although this method may in fact result in the choice of an appropriate index, it does not eliminate the problems.

Body mass index (BMI) has become the medical standard for measuring overweight and obesity. BMI uses a mathematical formula based on an individual's height and weight. BMI equals weight in kilograms divided by height in meters squared (BMI = kg/m^2). For people to determine their own

BMI, a graphical table is provided to the public as an alternative. A BMI of 25 to 29.9 indicates a person is overweight. A person with a BMI of 30 or higher is considered obese. The rationale behind these definitions is based on epidemiological data that show increases in mortality with BMIs above 25 kg/m^2 (WHO 1995; Van Itallie, Lew 1990; Van Itallie 1985; Manson et *al*. 1987; Troiano *et al*. 1996). The increase in mortality, however, tends to be modest until a BMI of 30 kg/m^2 is reached (WHO 1995; Manson et *al*. 1987; Troiano *et al*. 1996). For persons with a BMI of 30 kg/m^2, mortality rates from all causes, and especially from cardiovascular disease, are generally increased by 50 to 100 percent above that of persons with BMIs in the range of 20 to 25 kg/m^2 (WHO 1995; Manson *et al*. 1987; Troiano *et al*. 1996). Like the weight-to-height table, BMI does not show the difference between excess fat and muscle. BMI, however, is closely associated with measures of body fat. It also predicts the development of health problems related to excess weight. For these reasons, the BMI is widely used by health care providers.

There are, however, controversial issues related to the use of BMI. Recent studies have reported that these worldwide cutoffs have limitations, since they need to be defined by regional or ethnical differences. Although obesity-related diseases became a major public health issues in Asian countries, the prevalence of obesity based on the BMI cutoff of 25 kg/m^2 is low in those countries. Wang et al. (1994) reported that Asians have a lower BMI but a higher percentage of body fat than whites. Later, Deurenberg-Yap et al. (2000) confirmed that the relation between BMI and a percentage of body fat in Singaporeans is not only different from whites, but that it is also different among the three main ethnic groups in Singapore such as Chinese, Malays, and Indians. For the same BMI, age, and gender, the Chinese had the lowest percentage of body fat, whereas the Indians had the highest. The current BMI cutoffs were based on the western population. Therefore, the cutoff points of 23 kg/m^2 for overweight and 25 kg/m^2 for obesity were defined by the International Obesity Task Force (IOTF) for Asian adults in the Asian and Pacific regions (WPRO 2000). That is, people in Asian and pacific regions need to have lower cutoffs than those in other regions. Obesity means excess fatness of body. Especially an excess in abdominal fatness is related to chronic degenerative diseases. However, Deurenberg-Yap *et al*. (2000) reported that Chinese, Malays, and Indians in Singapore have lowest BMI and highest percentage of body fat. Jee *et al*. (2002) found that Koreans have high waist-hip ratio (WHR) and low BMI due to cigarette smoking in both males and females by using data from the Korean Nationwide Health Examination Survey. Some also have shown that waist circumference and WHR are more sensitive indicators of abdominal (central) obesity than BMI (Donahue *et al*. 1987, Lapidus *et al*. 1984, Rimm *et al*. 1995). Therefore, in WHR was used as an indicator of overweight and obesity in this study. WHR is obtained by dividing the waist circumference by the hip circumference. Men with a WHR 0.90-0.99 and women with a WHR 0.80-0.84 were classified as overweight, while men with a WHR≥1.00 and women with a WHR≥0.85 were classified as obese (WHO 1998).

2.2. Determinants of obesity

2.2.1. ① Diet

Diet plays a significant role both in onset and control of overweight and obesity. Although for years doubt about the contribution of excess food intake to obesity existed, a recent study clearly showed that obesity is associated with increased food intake (Lichtman *et al*. 1992). Excess intake of fat, among all nutrients, has been a major cause of obesity for decades (Lissner, Heitmann 1995). A study by Bolton-Smith and Woodward (1994) showed that diet composition has an important effect on relative weight because fat provides more energy than protein or carbohydrate per unit weight. Diet composition can also affect food intake, energy metabolism, and substrate oxidation. High fat foods are preferentially selected by consumers because of their high palatability and a low satiety effect. A continuing body of evidence links dietary fat intake to body fat, probably because of the energy density of fat, that is, high-fat diets tend to be high-energy diets (Bray, Popkin 1998; WIN 1998). Actually, there is no evidence linking carbohydrate intake to obesity risk (Bolton-Smith 1996) on a population basis. Satiety relates to appetite control and consequently to weight regulation. Available evidence suggests that protein is more satiating than carbohydrate or fat; high-fiber carbohydrate has a satiety index nearly comparable to protein. In their natural state, fruits and vegetables provide fewer calories than other choices, especially if they replace foods high in fat (U.S. Department of Health and Human Services 1995, 1998).

Feeding behavior consists of decisions about initiation, composition, and termination of meals; these decisions are influenced by many internal and external factors (LeMagnen 1992). Prepubertal children allowed to consume food *ad libitum* over six days from a menu consisting of foods they liked showed wide variation in calories consumed per meal, but total daily energy intake was relatively constant (Birch, Johnson 1991). This suggests that, with presumably little knowledge of nutrition, children sense the number of calories they have consumed and tend to keep their caloric consumption relatively stable. It should be noted that energy intake must exceed energy output in the growing child. This excess of intake over output is especially pronounced during rapid growth periods in infancy and adolescence. In contrast, energy intake must equal output in the adult, whose body composition is constant. Theoretically, it may be possible to exploit therapeutically the differences between children and adults in systems regulating energy homeostasis so that an imposed degree of body fatness will be defended once growth ceases.

2.2.2.② Physical activity

The advent of the automobile allowed many activities which previously had required more physical effort. The beginning of the internet era has enabled people to complete the same tasks at their desk which previously regarded physical effort. A strong link exists between physical inactivity and weight gain. Several cohort and cross-sectional studies have shown an association between obesity and inactivity (Williamson *et al*. 1993). A strong association of overweight and obesity with a sedentary lifestyle and physical inactivity was found in adults in a sample of 15 member countries of the European Union (Martinez-Gonzalez *et al*. 1999). There is a possibility that this relationship is bidirectional, with obesity discouraging physical activity and inactivity promoting weight gain (DiPietro 1995). Physical inactivity enhances the severity of other risk factors, but it also has been shown to be an independent risk factor for all-cause mortality or CVD mortality (Leon 1997).

Obesity prevalence was related to physical inactivity and television viewing in a study of 712 children aged 9 to 16 years in Mexico City (Hernandez *et al*. 1999). Television viewing promotes obesity by reducing physical activity and encouraging eating by external stimuli such as the sight, smell, and taste of food. TV viewing will be discussed again in ⑦ food choice.

For many people, even when calorie intake is not above the recommended level, the number of calories expended in physical activity is insufficient to offset consumption. All this can lead a person to be overweight and even obese (NIH 1996; French *et al*. 2001). Insufficient data are available for determining the particular roles of physical activity in weight loss and weight gain or regain. A better understanding is needed for activity profiles that lead to weight loss, weight loss maintenance (including the role of activity intensity and amount), and the prevention of weight gain. This area of research suffers from fundamental methodological problems in measurement. Research is needed on the development of technologies to better quantify actual energy intake and measurement of physical activity in free-living people over extended periods of time.

2.2.3.③ Energy balance or regulation of body weight

Even though we can control dietary intake and physical activity, maintenance of weight is not that simple. Epidemiological studies of the relative constancy of body composition over long periods of time strongly support a biological basis for the regulation of body fat. There is relative stability of body weight over time in most individuals, despite wide variation in energy intake and expenditure (Belanger, Cupples, D'Agostino 1988). Weight reduction therapies have poor long-term results: 90 to 95% of adults and children who lost weight returned to their previous state (NIH 1985; Wadden 1993; Rosenbaum, Leibel 1988). This suggests that attempts to maintain an altered body weight are opposed by systems of energy homeostasis (Rosenbaum, Leibel 1998).

According to the Framingham study, simply increasing caloric intake by 150 calories per day above weight maintenance calories per kilogram of usual body weight results in an average weight gain of only around 20 pounds in adults between 35 and 55 years of age, which is five pounds lower than if body weight were not regulated (Belanger, Cupples, D'Agostino 1988). Decreases in body weight of both obese and never-obese adults are resisted by equivalent declines in energy expenditure (Leibel 1984; Leibel, Rosenbaum, Hirsch 1995). To maintain a normal body weight, a formerly obese individual requires 100% to 15% fewer calories than a never-obese individual of the same body composition (Weigle, Brunzell 1990; Weigle, Sande, Iverius 1988). This decline in 24-hour energy expenditure primarily reflects a decrease in nonresting energy expenditure, during as physical activity, and resting energy expenditure (Leibel, Rosenbaum, Hirsch 1995; Weinsier, Nelson, Hensrud 1995). Maintenance of an increased body weight is resisted with equal metabolic force (Rosenbaum, Leibel 1988). The metabolic forces opposing the maintenance of an altered body weight are equally potent for obese and never-obese adults and oppose weight gain as strongly as they oppose weight loss. It is also notable that caloric requirements for weight maintenance are normalized for body composition. There are no significant differences in the metabolic requirements of lean and obese individuals to maintain their body weight (Rosenbaum, Leibel 1988). Thus, the view that obese adults suffer from a metabolic abnormality at their usual body weight is incorrect.

A formerly obese individual, however, requires substantially fewer calories to maintain body weight than a never-obese one of the same body weight and composition (Leibel, Rosenbaum, Hirsch 1995). Studies of adults who maintain a 10% reduced body weight have shown that the mechanical efficiency of skeletal muscle is increased after weight loss (Segal, Rosenbaum, Chatr-Aryamontri 1995). Adults who have maintained reduced body weight for several years continue to demonstrate the metabolic opposition to the maintenance of a reduced body weight (Leibel, Hirsch 1984).

There are two systems in the body that are primary regulators of the efficiency with which energy is used: the autonomic nervous system activity and the thyroid axis. The parasympathetic limb of the autonomic nervous system includes the vagus nerve. Increased parasympathetic nervous system slows the heart rate and increases insulin release (Butera, Bradway, Cataldo 1993; Woods, Chavez, Park 1996; Bray 1995; Geary 1996), i.e., favors weight gain. Increased output from the sympathetic limb of the autonomic nervous system stimulates thyroid hormone release, increases heart rate, decreases insulin release, and increases thermogenesis in brown adipose tissue (Butera, Bradway, Cataldo 1993; Woods, Chavez, Park 1996; Bray 1995; Geary 1996; Trayhurn 1986), i.e., favors weight loss. Thyroid hormone increases energy expenditure by increasing heart rate, blood pressure, and energy expenditure (Danforth, Burger 1984). Obese and never-obese adults demonstrate significant increases in parasympathetic nervous system activity and decreases in sympathetic nervous system activity at their usual body weight, during weight loss, and during maintenance of a reduced body weight and decreases in circulating concentrations of thyroid hormone both during weight loss and maintenance of a reduced body weight as compared with usual weight (Rosenbaum, Hirsch, Leibel 1998; Aronne, Mackintosh, Rosenbaum 1995). The increases in parasympathetic nervous system activity and mechanical efficiency of skeletal muscle and the decreases in sympathetic nervous system activity and circulating concentrations of thyroid hormone during maintenance of a reduced body weight are consonant with the declines observed in resting and nonresting energy expenditure.

An important question is whether an individual destined to become obese demonstrates increased metabolic efficiency before actually becoming obese. Many of the rodent genetic models of obesity demonstrate increased metabolic efficiency within the first few weeks of life before obesity occurs (Coleman 1982; Coleman 1990; Bray, York 1971; Bray 1981; Trayhurn 1984). Roberts *et al*. (1988) examined resting metabolic rate and 24-hour energy expenditure in three-month-old infants born to both lean and obese mothers. Twenty-four-hour energy expenditure was significantly lower at three months in those infants who were obese by the age of one year. The finding that 24-hour energy expenditure, but not resting metabolic rate, was significantly lower in infants destined to become obese suggests that the lower 24-hour energy expenditure is attributable to a decrease in the quantity of energy expended in physical activity. Similarly, low energy expenditure, adjusted for body composition, was associated with a fourfold increase of gaining more than 7.5 kg over two years in a study of adult Southwest Native Americans (Pimans) (Ravussin, Lillioja, Knowler 1988). Weight reduction in some obese individuals may unmask the metabolic state that predisposed them to become obese. In this sense, the extra body fat of the obese may mediate (Ravussin, Pratley, Maffei 1997) a metabolic correction for low energy expenditure. However, other studies (Davies, Day, Lucas 1991; Goran, Figueroa, McGloin 1995) have not found that reduced energy expenditure was predictive of subsequent weight gain.

The ventromedial hypothalamus (VMH) and lateral hypothalamus (LH) have important effects on feeding behavior (energy intake) and autonomic regulation of energy expenditure (Corbett, Keesey 1982; Keesey *et al*. 1975). Lesions of the VMH render rats hyperinsulinemic, hyperphagic, and hypometabolic compared with their sham-operated littermates (Sclafani 1994; Vilberg, Keesey 1984). The lesioned animals behave similarly to an underfed rat (Dulloo, Girardier 1993). Once they have reached a certain level of increased adiposity, lesioned rats eat the same quantities of food as their lean sham-operated littermates and no longer gain weight at a comparatively excessive rate (Keesey 1989; Keesey, Corbett 1984; Grossman 1975; Hoebel, Teitlebaum 1966). These lesioned animals will consume excess calories and gain excess weight to achieve a certain degree of fatness and then will defend that degree of fatness by appropriate adjustments of food intake, which suggests that the VMH lesion may have altered a set point for body weight (Keesey *et al*. 1975; Keesey, Corbett 1984; Grossman 1975; Harris 1990). Similarly, rats with lesions of the LH become hypermetabolic and hypophagic (Keesey *et al*. 1984,Corbett, Keesey 1982, Keesey, Corbett 1984). The VMH and LH areas are, therefore, viewed more accurately as subserving and integrating complex systems regulating both feeding behavior and energy expenditure (Powley, Laughton 1981; Sclafani, Springer 1976; Sclafani 1981). Evidence for the presence of similar regulatory centers in humans is provided by the observation that traumatic or infectious injury to the human hypothalamus results in a syndrome characterized by hyperphagia, hyperinsulinemia, and overactivity of the parasympathetic nervous system (Bray, Inoue, Nishizawa 1981; Bray, Gallagher 1975).

2.2.4.④ Genetics

The ability to conserve energy as adipose tissue is important for individual survival and reproductive capacity (Frisch, McArthur 1974). Humans may be enriched for genes that promote energy intake and storage and that minimize energy expenditure. Such genes would also enhance female fertility and breastfeeding. However, in the environment that increases access to calorie-dense foods and sedentary lifestyle, the metabolic consequences of these genes are maladaptive (Neel 1962; Mueller 1983).

There are rare instances of single gene disorders that result in human obesity (Leibel, Bahary, Friedman 1990). Studies of twin, adoptee, family, and animal models of obesity indicate that obesity is a result of both genetic and environmental factors (Hager *et al*. 1998; Stunkard *et al*. 1990; Friedman, Halass 1998). It has been suggested that genetic susceptibility may be expressed through adipose tissue distribution (intraabdominal versus subcutaneous fat), low resting metabolic rate (Astrup *et al*. 1999), decreased rate of lipid oxidation, impaired appetite regulation, altered hormonal release or sensitivity, lipoprotein lipase activity, or response to overfeeding (Bouchard *et al*. 1999). Basal rates of lipolysis are estimated to be as high as 30% to 40% (Rosenbaum, Leibel 1988; MacDougald, Lane 1995).

It is well-known that if either or both parents are overweight, a child is more likely to have weight problems. Using a cross-sectional study, Fogelholm *et al*. (1999) found that parent obesity (BMI≥30) was a strong predictor of child obesity (odds ratio 2.38-3.50, $P<0.002$). Two cohort studies found that the parents' BMIs accounted for 13.5% of the children's relative BMI variance at the age of 12 years ($R = 0.37$, $P < 0.001$) (Maffeis, Talamini, Tato 1998); and BMI in 18-year-old sons (48% of variance) and daughters

(33%) was significantly predicted by mothers' and fathers' BMI (Burke, Beilin, Dunbar 2001). However, authors could not distinguish genetic predisposition from environmental factors. Segregation analyses in which the relation of obesity to family is examined under various genetic models have found evidence for segregation of major genes (allele frequencies, 0.14 to 0.26) influencing BMI (20% to 35% of variation) in human populations (Bouchard 1994). The heritability of early-onset obesity appears to be considerably higher than that for adult-onset obesity (Stunkard, Sorensen, Hanis 1986). What is likely to be inherited most strongly is the rank order of body fat relative to one's peers within a population in the same environment. One study suggested that the genetic influences on body weight are as potent as those on height (Stunkard, Foch, Hrubec 1986).

Human body sizes are polygenic in origin and the full characteristics of each gene's expression are further influenced by the environment. Maes *et al*. (1997) investigated correlations of BMI for monozygotic and dizygotic twin pairs and for offspring pairs of the same biological parents and adoptive relative pairs based on about 100,000 individuals: a weighted mean BMI correlation of 0.74 was obtained for monozygotic twins compared with 0.32 for dizygotic twins; and correlations for biological parent-offspring pairs and adoptive relative pairs were 0.19 and 0.06, indicating a smaller role for a shared environment. However, both coefficients are low, and this does not preclude the importance of environment or the unspecified power of control we have over these external factors.

From studies of Pima Indians living in Mexico and their close relatives living across the border in the U.S., it is obvious that cultural environment plays a great role in determining the phenotype for these Indians, especially as regards choices of foods available. Krosnick (2000) says of the Pimas in the U.S, "The Pima Indians are the fattest population group in the fattest country on earth." However, those in Mexico live mainly on grains and vegetables and do not have access to the high-caloric fatty foods available to the U.S. Pimas. Thus, they are slender, while those in America are obese. This suggests that perhaps the environment plays a role by amplifying the expression of the phenotype of the individual based on his genes. Some mouse studies have shown that small differences in adiposity among inbred strains are magnified by a high-fat diet (West 1994a; West 1994b; West 1995; York *et al*. 1999). Hence, while both the Mexican and American Pima Indians have genes that predispose them to becoming obese, the unavailability of fatty foods prevents these genes from becoming expressed phenotypically in the Mexican Pimas. A recent review based on studies of Pima Indians reveals that metabolic rate, fat oxidation, spontaneous physical activity, and genetic factors explain 12%, 5%, 10%, and 40% of the variability of BMI respectively (Ravussin and Bogardus 2000). The remainder is apparently related to environmental factors that influence weight gain. In fact, many studies show that populations which have previously tended towards being underweight tend towards obesity after urbanization and the consequent sedentary lifestyles and high-calorie diets associated with city life (Uauy, Albala, Kain 2001; Seidell 2000).

Results from reported genome-wide linkage studies that examined obesity and related intermediate traits have identified several loci that show evidence of genetic linkage (Barsh, Farooqi, O'Rahilly 2000). In a study by Comuzzie *et al*. (1997), significant correlation was found between obesity and levels of serum leptin (serum leptin decreases hunger and food consumption, mediated at least in part by inhibition of neuropeptide Y synthesis, and increases energy expenditure levels to markers on the short arm (p) of chromosome 2 at band 21 (2p21)). A study by Hager *et al*. (1998) shows three putative gene loci for obesity and leptin levels on chromosomes 10, 5, and 2, suggesting that the locus on chromosome 10p may account for 21-36% of the obesity in the study population. Another study by Rotimi *et al*. (1999) confirmed chromosome 2 linkage for serum leptin levels in a population of African-Americans. Kissebah *et al*. (2000) revealed two 3-quantitative trait loci (QTLs) in chromosomal regions containing candidate genes that could affect expression of the metabolic syndrome. The metabolic syndrome is the close interaction between abdominal fat patterning, total body adiposity, and insulin resistance. Insulin resistance leads to an increase in hunger, a higher set point, and decreased thermogenesis. A genome-wide scan using a 10-centiMorgan map in 2209 individuals distributed over 507 nuclear Caucasian families, followed by pedigree-based analysis using a variance components linkage model, demonstrated a QTL on chromosome 3q27 strongly linked to six traits representing fundamental phenotypes (waist circumference, leptin, insulin, insulin/glucose ratios, hip circumference, and BMI). This QTL exhibited what is possibly an epistatic interaction with a second QTL on chromosome 17p12 strongly linked to plasma leptin levels (Kissebah *et al*. 2000). Evidently, predisposition to obesity is determined by many genes, across many chromosomes, but these studies are performed using different measures or indicators of obesity and are performed on populations where environmental influences are difficult to hold constant.

Mutations in a single gene cause only about 5% of cases of obesity. The number of genes and markers associated with human obesity is more than 200 (Zekanowski 2001). Thus, performing meta-analysis across different studies, with different populations and environments, and accounting for multiple gene interaction is a difficult task. It requires communication by researchers with specialities such as the human obesity map as in Hager *et al*. (1998), single-nucleotide polymorphism (SNP) analysis around suspicious genes, and research on data normalization across different parameters. Currently, despite extensive efforts by numerous groups, progress has been slow, and only a few genes and some genomic regions involved have been identified. Genome-wide association studies are now feasible through the use of PCR methodologies with pooled DNA samples and microsatellite variation and, more recently, SNP variation (Thomson 1995). With the completion of the rough draft of the human genome, better genetic regulatory models of obesity may eventually allow better diagnosis, using suspension arrays for SNP genotyping (Armstrong, Stewart, Mazumder 2000) or high-density oligonucleotide arrays of SNP markers (Sapolsky *et al*. 1999) for genetic predisposition.

Environmental factors should be investigated to explain what is behind the current rise in obesity. If individuals with a potent genetic predisposition to obesity are still lean in an environment of food deprivation or high demand for physical activity, while individuals without a genetic predisposition to obesity may still become obese in an environment with lots of caloric-dense foods and low physical activity, phenotypes are unlikely to be inevitable regardless of the environment.

2.2.5.⑤ Price effects on diet and physical activity

Price is the main factor that is affected by trade liberalization. Price could affect diet and physical activity directly or indirectly as mediated by income effects, since price changes bring both substitution and income effects. If a price of a good goes down, people can buy more of that item as well as others. Prices of food commodities are important determinants of food choices, with potential consequences for food and nutrient availability. Because different foods provide different nutritional profiles, changes in food prices or in consumer income are likely to translate into changes in the foods purchased and the quantity and quality of consumer diets.

Among the emerging trends in the global diet, there is an increased availability of vegetable fats at affordable prices even for the lowest income group (Drewnowski, Popkin 1997). The dietary transition in developing nations typically begins with major increases in domestic production and imports of the oilseed and vegetable oil group, whereas Westernization of the global diet continues to be associated with increased consumption of animal fats (meat and milk) due to increased availability (Drewnowski, Popkin 1997). The falling price of vegetable fat in the international market and the rising price of fruit and vegetables in the domestic markets are common factors in Asian countries that experience the nutrition transition (Reddy 1999). With the growing preference for fatty processed food, the consumption of foods rich in micronutrients is discouraged due to their higher cost than processed food (WHO 2001).

In the U.S., the relative prices of dairy products, fats and oils, eggs, meat, poultry and fish, and sugar and sweets have dropped dramatically over the period 1982-1997, as has the price of non-alcoholic beverages (dominated by carbonated sweetened soft drinks) (Putnam and Allshouse 1999). Future projections of the internationally traded prices for non-staple, non-fruit, and non-vegetable foods suggest a further decline in their prices relative to cereals (Delgado *et al*. 1999).

The main issue of diets in areas of overweight and obesity is high caloric intake due to sugar and fat or oil and fat intake. More analyses need to be undertaken from a health perspective of past trends in producer and retail food prices. Such trends would help identify the main sources of any decline or increase in the price of fat or added sugar, which would obviously be important for policy formulation. In addition, there need to be more studies linking price trends to health outcomes. There are many studies linking undernutrition outcomes to price changes (Pitt, Rosenzweig 1986) but few linking rates of chronic disease or levels of obesity to relative price changes, controlling for a range of other factors. One view emerging from such studies with U.S. data suggests that 40% of the growth in weight of the U.S. population between 1976 and 1994 was due to technology-based reductions in food prices (Lakdawalla, Philipson 2002; Philipson, Posner 1999). When China entered into the WTO, the consumer prices of soybean oil and related products were decreased by 20% (Fang and Beghin 2000).

Bourne *et al*. (1993) discovered that the vegetable consumption among the urban African population on the Cape peninsula was very low. When purchasing power increases, domestic vegetables are often replaced or supplemented by imported and more exotic ones, which also increases variety in the vegetable supply (Hatloy *et al*. 2000). Fruit consumption increases with economic status (Fouere *et al*. 2000; Hatloy *et al*. 2000; Ahmed *et al*. 1998). Imports of fruit allow more fruit variety in the diet. The fruit supply was larger in the late 1990s than in the early 1970s in both developing and developed countries. The increase was also greater in Asia. The consumption trends varied from country to country.

Recently, developed countries have considered taxes on fat from the health perspectives (Marshall 2000; Santarossa, Mainland 2003). However, the relationship between food intake, obesity, and disease is complex and care needs to be taken in assessing public intervention. For example, Kennedy and Offutt (2000) have argued that the fat tax proposal would be regressive and ineffective. This type of tax regime is likely to be ineffective if its impact is only to shift consumption between food items without changing the total caloric intake. It is argued that fat taxes are regressive because poorer people spend a higher proportion of their income on food and poorer people tend to suffer most from obesity (Cash *et al*. 2005).

There are possible effects of the price of health facilities on physical activity. However, the cost of physical activity is not a necessary component for all households and the effect would be lower than the cost of foods. For industrialized countries and middle or higher income groups, the association should be investigated.

2.2.6. ⑥ Income effects on diet and physical activity

Increased income can enhance command over commodities. Income can affect diet and physical activity directly, most especially by affecting food choice (Tullao 2002). The most beneficial effect of increased income is increased access to food (Powles 2001). People are now able to enjoy a longer life span coupled with enhanced access to medication, health services and sanitation, and information (Tullao 2002). Increasing access to food has reshaped the consumption patterns of people across their life span.

Income can also influence individual food choices. As income increases, consumers want to diversify beyond cereals and other starchy staples. Data from USDA (Regmi 2001) on how food expenditure responds to an increase in income (food expenditure-income elasticities) across a number of developing countries show that the poorest countries have the highest elasticities. Fish, then dairy, and then meats have the highest values, followed by fruit and vegetables, oil and fat, and lastly cereals. Elasticities may increase in the short term. For example, in China the income elasticities for pork and oil increased between 1989 and 1993, and more so at the lowest income levels, especially for edible oil (Guo *et al*. 2000).

An increase in income shifts food consumption patterns towards intake of fats, meat, and processed food. The growing acceptance of fatty and processed food with poor nutritional value is a threat to public health, domestic food security, and traditional food economy. Dietary preferences have turned in favor of imported processed food. As prices of these commodities decrease with the reduction of tariffs brought about by trade liberalization, the lack of adequate food safety standards and regulations has opened the door to low-quality processed food that may result in serious health risks such as obesity. As a growing number of people consume more fatty processed food, they are now more prone to diseases linked to obesity (Tullao 2002).

People who were unemployed or who had irregular income consumed street foods more often than people who were regularly employed (Van Riet *et al*. 2001). Fouere *et al*. (2000) discovered that devaluation of the currency increased the use of street foods in the capital cities of Senegal and Congo because buying street foods saved not only on the cost of the food ingredients but also on the cooking fuel and preparation time.

There is an inverse association between income and body weight in men and women in developed societies (Sobal, Stunkard 1989). Overall, income has been a powerful predictor of body weight levels and obesity. In developed countries, females with higher incomes are thinner and less likely to be obese. Income permits people to avoid or overcome overweight and obesity and is a component of interventions to prevent or reduce obesity.

Komlos *et al*. (2003) hypothesize that an increase in the marginal rate of time preference contributes to the obesity epidemic. Time preference refers to the rate at which people are willing to trade current benefits. Various factors influence a person's time preference. Increased income means that one has more economically valuable time than before. People therefore want to spend less time on cooking preparation and have more meals away from home than before. Supply and demand for meals away from home will increase as female work participation increases. It is becoming more common to eat meals away from home or to eat prepared meals. Egyptians ate 46% of their meals away from home in 1998, compared to 20% in 1981. These figures include the meals eaten at the homes of relatives (Galal 2002). There was a five-fold increase in household expenditure on prepared meals from the 1960s to the 1990s in Mauritius even after taking inflation into account (Mauritius Ministry of Economic Development 1997). Eating Western fast foods is common only among low-income people in developed countries, but it is popular in the higher socioeconomic groups in the developing countries. Almost half of Malaysian urban Chinese, the majority of them belonging to the middle-income group, ate take-out foods more than once a week, and 54% of males and 37% of females preferred Western fast foods such as fried chicken, burgers, or pizza to other types of take-out meals. The researchers also noticed that the younger age groups especially favored eating these foods. (Khor, Hsu-Hage, Wahlqvist 1998). Exercise requires the expenditure of time and monetary investment such as membership in a health facility. A higher rate of time preference will lead to less investment in exercise and greater caloric intake, resulting in weight gain and increased obesity.

2.2.7. ⑦ Food variety and diet: food choice

Trade has the direct effect of expanding the availability of commodities and level of consumption (Tullao 2002). For the whole developing world, the per capita consumption of beef, mutton, goat, pork, poultry, eggs, and milk rose by an average 50% per person from 1973 to 1996 (Pinstrup-Andersen, Pandya-Lorch 2001). In most of the developed and many of the developing countries, there is an overall abundance of palatable and caloric-dense food. Additionally, the abundance of food in the supermarket, the availability of food sold at fast food restaurants and vending machines, and the large portions of food served outside the home promote high caloric consumption. Holidays or special occasions also promote overeating and preferential consumption of high caloric foods.

The considerable rise in the vegetable oil supply worldwide over the past 30 years has already been made. Dietary transitions start with increased consumption of cooking oils. The remarkable increase in vegetable oil availability in developing countries suggests that a dietary transition is occurring. The relative increase in the availability of oil in 1970-1999 was larger in developing countries than in developed countries, 124% and 50%, respectively. Butter and ghee consumption has been much lower than oil consumption in the developing world. However, while the per capita supply of these saturated fats was decreasing in the developed countries between 1970 and 1999, the supply had an upward trend in developing countries. The average butter and ghee supply almost doubled in the low-income countries and in Asia between 1970 and 1999 (Drewnowski, Popkin 1997). It is important that a major part of fat consumption is hidden in prepared dishes and individual preferences regarding the amounts of fat used for food preparation are difficult to detect.

The quality of fat is at least as important as the quantity of fat (Kromhaut 2001). Milk availability has increased throughout the world since 1970, except in Africa. Milk and egg consumption trends, however, varied from country to country. Processed milk and powdered or condensed milk are more available in urban areas (Hatloy *et al*. 2000). Increasing trends both in supply and consumption of sugar and sweetened drinks has been found throughout the developing world, while in the developed countries it has decreased. Only India and Morocco reported in their survey results that sugar consumption has decreased. The Western fast food industry carries out widely distributed marketing in the developing world, including advertisements for carbonated soft drinks. There is hardly any urban area in the world that does not have advertisements for popular soft drinks.

According to Uusitalo, Pietinen, Puska (2002), the meat supply increased worldwide from 1970 to 1999, especially in Asia. However, meat consumption did not match these trends and decreased in the same period according to the survey results from various nations. Meat is consumed in different forms. Processed meats have become more popular, and sometimes sausages or canned meat are not considered real meat, leading to an underestimation of meat consumption (Uusitalo, Pietinen, Puska 2002). Poultry supply and consumption and fish supply and consumption have consistent increasing trends worldwide. It is clear that the energy density of diets is increasing worldwide. The share of energy from animal protein has increased from 3.1% to 18.9% in China in 40 years (Uusitalo, Pietinen, Puska 2002).

2.2.8. ⑧ Occupational structures

Some studies find that women who are not employed are more likely to be obese than their counterparts who participate in the labor market (Sobal, Rauschenbach, Frongillo 1992), while unemployed men have been reported to be underweight (Montgomery *et al*. 1998). Activity level and caloric intake from employment are not well identified and hardly known. Females in low prestige jobs tend to be more obese, but the relationship between occupation and weight is less consistent for men (Pagan, Davila 1997). Energy intake is not necessarily determined by occupation, but energy expenditure varies by occupation. Some jobs require extensive physical activities, while others spend many sedentary hours on the job. Doing physical exercise varies across occupations. Thus, occupations are related to diets and physical activity.

Industrialization leads to reduced physical activity, at work and at home, for both gender. As occupations shift from agriculture and manual labor to manufacturing and the service sector, the levels of energy expenditure decrease (Popkin, Horton, Kim 2001). In addition, with the upsurge of knowledge-based industries accompanying the expansion of information and communication technology, workers may be confined to interacting with computers, telephones, machinery, and equipment.

Highly mechanized companies have employed robots to replace human workers in production (Tullao 2002). People are now confined by routine and activities requiring less physical exertion. According to Powles (2001), physical activity levels have declined substantially, especially since the mid-20th century. Physical inactivity has a direct effect on health and is considered one probable cause of the rising prevalence of obesity.

2.2.9.⑨ Public transportation

Numerous environmental factors can facilitate or limit physical activity. Increased public transportation and its convenience could decrease physical activity. Rapidly increasing urbanization has resulted in a increased dependence on mechanized transportation and the disappearance of public spaces for physical exercise by increasing inexpensive public transportation and communication systems that discourage physical activity (Brody 1992; Schneider 2000; Sobal 2001). In addition, as suburbs expand around large urban cent
ers, there is an greater dependence on transportation system than before, as well as a loss of fields where outdoor activities previously happened (Schneider 2000; Sobal 2001).

2.2.10.⑩ Trade liberalization

Specialization for the comparative advantage of trading countries has resulted in efficient use of their resources (Tullao 2002). The efficiency gains in production and activity distribution sequentially have brought about lower prices for traded goods, including agricultural products and manufactured food (Tullao 2002). Trade liberalization increases people's choices in food and decreases the food prices. It also changes occupational structures in a country. The movement of production to where a company has comparative advantage can increase the country's employment opportunities and income (Tullao 2002). If these developments use properly, they can improve access to food and health services. While the phenomenon may create transitional unemployment in a displaced sector, this is temporary and expected to be offset by job creation in new sectors (Pinstrup-Andersen, Babinard 2000).

Trade liberalization has undeniably created employment and income opportunities particularly in the export sector; therefore, it brings displacement of labor, unemployment, and lower income to different sectors than before (Tullao 2002). It can also create adjustment costs that may be serious in developing nations due to the rigidities in the adjustment process (Tullao 2002). For example, industries that are concentrated in a few sectors and geographic areas can make labor and other resources difficult to move towards emerging sectors (Pinstrup-Andersen 2000). The decreased income of displaced workers means limited access to food, nutrition, and health services (Tullao 2002).

Trade liberalization increases opportunities to consume (Tullao 2002). There has been a remarkable raise in the global commerce of high value-added products. It is estimated that in 2000 about 75% of agricultural trade consisted of high value-added products, a rise from 50% in 1985 (Tullao 2002). This shift from unprocessed foods towards high value added ones were brought about by increased income and product differentiation (Josling 1999). Food demand in developed countries is also becoming more diversified and quality-oriented due to trade liberalization (Fresco 2000). The variety of food available and selection to consumers worldwide has increased through global trade (Ruppel, Malanoski, Neff 1996). The changes in income and diets resulting from trade liberalization can consequently bring enhanced nutrition, on one hand, and new nutritional problems, on the other hand (Pinstrup-Andersen, Babinard 2000).

Trade liberalization allows local food industries to compete with global suppliers; entry of cheap imported food threatens domestic food producers, especially in countries with less developed food production systems (Tullao 2002). A surplus in cheap food coming from other countries can potentially displace local producers. One of the reasons why the price of beef is more expensive in South Korea than in the U.S. is the government protection to this very sensitive industry at the cost of consumers. The influx of cheap imported processed food has also changed the food consumption patterns away from a traditional diet based on domestic food production (Popkin, Horton, Kim 2001). The trade in processed food is not just about the trade of goods but it involves production systems and cross-border relationships (Henderson, Sheldon, Pick 2000). Processed foods and beverages are value-added products, in that combination of labor and technology is applied to raw commodities, such as sugar and water, which are transformed into a new product, such as soft drinks (Tullao 2002).

The U.S., Western European, and Japanese companies dominate the global food processing market (Tullao 2002). The 50 largest firms are in these countries and account for about 40 percent of their gross output of manufactured food (Henderson, Sheldon, Pick 2000). People in the U.S. have enjoyed a wide variety of processed food from all over the world in the same manner that global consumers have enjoyed access to U.S. food brands (Ruppel, Malanoski, Neff 1996). The processed food trade grew from 40 to 50 percent over the 1965 to 1985 period and grew further to 60 percent in 1995. Global food exports in 1995 were 3.5 times as high as in 1985. However, the trade of raw agricultural commodities increased only 1.5 times over this period (Rae, Josling 2001).

Food retailing systems have been also changed. The percentage of food distributed by supermarkets in retail outlets has been increasing in Latin America, Asia, and Africa (Reardon *et al*. 2003). Whether these supermarkets bring poor consumers greater access to unhealthy processed foods or fresh fruits and vegetables is a question to be answered.

Trade liberalization may reduce tariffs on alcohol as part of its WTO commitments (Tullao 2002). Significant tariff reduction may increase the overall alcohol consumption and may bring health implications (Gould, Schacrer 2002). Although global nicotine addiction has been accompanied by income growth, tariff reduction can also play a significant role in increased consumption (Peto 1994). To offset the effect of tariff reduction on consumption, a tax on cigarette consumption has been levied in Thailand (Tullao 2002).

Trade liberalization plays an important role in food security. With reduction of tariffs and trade barriers, imported food supplies can easily go into a country with any upsurge in food needs due to domestic production deficit (Tullao 2002). A liberalized trading regime can also enlarge the export sector that can make foreign exchange to finance food imports (Pinstrup-Andersen, Babinard 2000). However, the impact of trade liberalization on nutrition and consequently on overweight and obesity will rely on the quality of food intake developed from such a liberalized regime (Tullao 2002).

Trade liberalization however, causes uneven access to food. Although food production and per capita supply has increased over time, the absolute number of undernourished people worldwide is still significant (Tullao 2002). Given the uneven impact of trade liberalization on various countries, it is estimated that the number of the undernourished in developing nations is 23 times higher than in developed ones (Fresco 2000). The problem is not the shortage of food but rather poor distribution (Kaosaard, Rerkasem 2000).

2.2.11.⑪ Urbanization

Urbanization can change diets and physical activity through a change in occupational structure as well as an increase in public transportation. Over the period 2000-2025, the urban population in the developing contries is expected to double, up to 4.03 billion, and the rural population is expected to increase from 2.95 billion to 3.03 billion (UNHCS 1996). The urban population in developing countries is growing three times faster (3 percent annually) than the rural (Ruel, Haddad, Garrett 2001).

Ruel, Haddad and Garrett (2001) explained that urbanization increased the labor-force participation of females, and it indirectly affected the family diet. Urbanization brings more store-brought and processed foods, rather than fresh animal products and garden produce (Solomons, Gross 1995). Traditional staples are often more expensive in urban areas than in rural areas, whereas processed foods are less expensive (Ruel, Haddad, Garrett 2001). Dirks and Duran (2001) found that urban African Americans to seek more novel foods because the staples were more expensive in urban than in rural areas. The shift from traditional staples to processed foods in the urban is strongly enhanced by the advocacy of Western culture through mass media and commercial marketing (Sobal 1999a).

Subsidies paid on staples may also change the staple preferences (Galal 2002). Urbanization independently leads to increased consumption of new types of grains such as milled grains (Drewnowski, Popkin 1997; Popkin, Bisgrove 1988). Processed and fast foods are more convenient than traditional staples, which require time and effort for preparation before eating. Rice, a main staple food in many Asian countries, gradually is replaced by wheat.

2.2.12.⑫ Global communication

Global communication could affect individual knowledge of obesity. Globalization of knowledge makes information available on the prevention and treatment of diseases including overweight and obesity via various sources. Significant opportunities in advancing health care are presented by making information available through various telecommunications networks, including the internet (Lee, Collin 2001). The globalization of knowledge about the determinants of diseases has demonstrated success in risk modification strategies and cost-effective interventions (Reddy 1999). However, this knowledge can lead to over or wrong diagnosis (Tullao 2002). Readily available medical, health, and nutrition information via various mass media can lead to self-medication (Tullao 2002). Given the conflicting conclusions of tentative studies on the impact of risk factors associated with chronic diseases, the use of this information may be harmful to some unsuspecting individuals without guidance of health professionals(Tullao 2002).

2.2.13.⑬ Individual health knowledge

The extent to which people gain and use new information has been related to levels of education obtained. More-educated individuals may place a higher value on future consumption than present one and may find optimal levels of activities to prevent health risks (Philipson *et al*. 2004). Individual health knowledge modifies the effects of other factors on diet and physical activity. Education provides knowledge that is used to decide diet and activity choices. Education also gives people the principal norms about fatness and thinness in a society (Sobal 2002). Males and females with the least education tend to be heavier than their counterparts (Sobal, Stunkard 1989). Overall, education is one of the strongest predictors of overweight and obesity in populations, with more highly educated people being thinner in developed countries and opposite being true in developing ones (Sobal 2002).

Lyons and Languille (2000), however, found that people keep unhealthy lifestyles even though they know how unhealthy they are due to immediate needs. Evans *et al*. (2001) reported that in Tonga consumers purchase imported fatty food and simple carbohydrates even though they know the various nutritional values of the food due to their easy and ready availability.

2.2.14.⑭ Globalization

Globalization refers to the process of growing linkage and interdependence of the world's welfare, information, and markets in the trade of goods, services, labor, technology, and finance. Its speed has increased with the development of new technologies, especially in the area of telecommunications. A broad view of globalization would include: 1) the increase of economic, political, social, and cultural linkages among people, organizations, and nations at the world level; 2) inclination in the direction of the universal application of economic, institutional, legal, political, and cultural practices; and 3) the spillover effects of the behavior of individuals and particular societies to the rest of the world (Diaz-Bonilla, Sherman 2001).

Globalization as an inevitable force brings asymmetrical opportunities and threats. What may be beneficial to one sector or country may be deemed detrimental to another in consideration of an uneven economic and social situation. Among its many aspects, trade liberalization, urbanization, and global communication will be employed as predictors on this study, as already mentioned. Here, I review several other aspects of globalization.

The integration of the global financial market makes accessible to countries funds for financing government development projects as well as plant expansion in the industrial sector. Even for the health services sector, these funds can be made available to augment deficient local resources for improving and arresting the deterioration of health services system in many developing countries.

However, integration of financial markets makes economies vulnerable to fluctuations in the global financial market. The risks and volatility of fluctuations in exchange rates under an integrated financial market were observed during the Asian financial crisis in 1997. A combination of rapid inflation and high unemployment rates reduced consumer spending, leading to nutritional deficiencies, as experienced in Indonesia (Pinstrup-Andersen 2002). Moreover, a health services sector that relies on external funding will have to adjust by charging very high prices for medical services wherever exchange rates fluctuate. When a domestic currency depreciates, the value of the country's foreign debt swells as measured in domestic currency. As a consequence, public services that have been financed by foreign funds - including health services - have to add an exchange rate adjustment fee to the price of the service whenever the exchange changes.

Once a country makes a commitment to open its health services sector under the General Agreement on Trade in Service (GATS), foreign health professionals, including medical service providers, have to be granted market access. The entry of foreign health providers has the potential to improve the quality of health services in the country, given their training, experience, and use of technology. Increasing trade in services thus allows the entry of foreign service providers who can improve the quality of medical services. However, this brings expensive health services. Non-discrimination is also required to facilitate entry of foreign service providers under the GATS rules, and foreign medical and health service providers will only enter a country if the consumers are willing to pay the prices appropriate to their training and experience and the technology being used.

Although globalization has created opportunities for the expansion of employment and income, it has widened the gap between the rich and the poor. At least 20 percent of the world population still lives in absolute poverty. It is estimated that the likelihood of infant mortality is five times higher in families in absolute poverty than in those in higher income groups. Access to health services for the poor has been exacerbated by the deterioration of local health systems in many developing countries. The GATS allows for non-discrimination in the granting of subsidies for public goods, including education and public health. In such an environment, given the limited funds of the government, this may divert the limited public funds for health services. Giving subsidies to foreign service providers would, in effect, divert public funds and might shift government focus away from either infectious diseases or NCDs.

Another aspect of globalization is globalization of culture (Tullao 2002). New information technology and biotechnological production processes have broadened industry opportunities for low-energy and recycling methods that have created new types of work organization (Loewenson 2001). The pursuit for efficiency and lower production cost is intended to help companies not only to make globally competitive but also to supply quality service and products (Tullao 2002).

The problem of today's economy is that globalization of markets is outpacing the necessary creation of governance and institutions for effective functioning in them at the national and international level. Globalization's opportunities are not equally distributed between nations and people. Stronger governance, an effective and credible governing process, could improve on the disparity. Structures for global policy-making are asymmetric; the powerful majorities, isolating the powerless minorities, dominate economic structures such as the IMF, World Bank, G-7, OECD, and WTO. Global public policies need to facilitate a more equal distribution of global public goods. In addition, they should improve global macroeconomic management to prevent crisis and instability, provide for firefighting responses to crises, and recognize the need for rules for international exchange and investment, research in public health and technology for the poor, and management of the global commons. Developing nations should make great efforts for active participation in the globalization process and developed nations should support them in this. That will not be easy, but it seems necessary for global well-being.

2.2.15.⑮ Other factors

2.2.15.1. Individual characteristics

2.2.15.1.1. Gender

Gender has both biological and sociocultural influences on body weight (Sobal 2002). Biologically, females tend to have more stored body fat and are more likely to be obese than males (Brown 1991; Kusczmarski *et al*. 1994). Socio-culturally, people have attitudes to fatness and thinness (Bordo 1993). Females are more judged by and more concerned about physical appearance than males because body shape is a major criteria for female attractiveness (Pliner *et al* 1990; Sobal, Maurer 1999a,1999b). Stigmatization of fat individuals is more common and more severe for females than males in the developed world (Sobal 1999b).

2.2.15.1.2. Age

Body weight is known to increase as age increases, and then to decline in the last decades of a person's life (Brown 1991; Flegal *et al*. 1998). It is difficult to separate the relative importance of biological versus social influences on weight by age (Sobal 2002). Activity levels of younger people tend to be higher and then to decline as people age (Martinez-Gonzalez *et al*. 1999). Eating patterns also differ throughout the lifestage (Devine *et al*. 1998).

2.2.15.1.3. Ethnicity

Attribution of racial or ethnic differences in body weight is extremely problematic (Winkleby *et al*. 1998). Studies of influences of ethnic differences on body weight in the U.S. showed that most minority groups are more likely to be obese than the majority (Flegal *et al*. 1998; Mokedad *et al*. 1999; Deurenberg *et al*. 1998). Many U.S. minority groups are more likely to accept higher body weights than those in majority groups (Rand, Kuldau 1990). There is no consensus about the relative contributions of genetics, dietary intake, or physical activity to ethnic weight differences (Kumanyika 1994, 1999).

2.2.15.1.4. Marriage

Marriage is related to body weight in many different ways (Sobal 2002). Obese people enter marriage later (Gortmaker *et al*. 1993) and marry heavier partners (Sackett *et al*.1975). People are more likely to attain weight after entering marriage (Craig, Truswell 1990; Kahn *et al*. 1990, 1991). Married males, but not necessarily females, weigh more than the unmarried (Sobal *et al*. 1992). People who end marriages tend to lose weight (Kahn *et al*. 1990, 1991; Rauschenbach *et al*. 1995). Effective interventions to modify or maintain body weights can be structured around marital partners (Burke *et al*. 1999).

2.2.15.2. Household characteristics

2.2.15.2.1. Family size and composition

The two most powerful factors, family size and composition, have effects on household demand and preferences for goods and services (Bryant

1990, p.73). Household size is related to income, expenditure, and time use of the household and, further, to diets and activity levels. Having a dependent affects the use of household resources, i.e., income and time.

For example, the arrival of a child has several effects on family members. From the economic point of view, the income and time allocation has to be changed. From the biological perspective, having a child is one of the major reasons for female being overweight or obese (Bradley 1985). A small association exists between parity and weight, with an average gain of about one kilogram per child (IOM 1990). However, averages may be misleading because some females gain and retain weight after childbirth while others lose (Williamson *et al*. 1994; Wolfe *et al*. 1997a, 1997b).

2.2.15.2.3. Residential locations

Whether a person lives in a rural, suburban, or urban area is related to overweight and obesity. In the U.S., rural females slightly tend to obese than their metropolitan counterparts (Sobal *et al*. 1996). Rural residents have slightly higher energy intakes (Windham *et al*. 1983). While energy expenditure in rural areas was traditionally high, the rise of mechanized farming and automobile transportation has decreased rural-urban differences (Sobal 2002). Urban people put more emphasis on thinness, leading people in urban areas to control their weight more actively (Sobal 2002). Only a few data exist about regional differences in overweight and obesity. In the U.S., obesity is most prevalent in the south and southeast. However, as the entire U.S. population becomes fatter, obesity has spread to most regions of the country (Mokdad *et al*. 1999). It is currently unclear why specific places have fatter or thinner populations, and more research on this topic is needed (Sobal 2002).

CHAPTER 3

METHODS

This chapter begins with explanations of the research design and methodology. Variables and data sources of the study are also presented. This is followed by a description of data analysis and modeling.

3.1. Research design and methodology

3.1.1. Korea National Health and Nutrition Surveys (KNHNS)

The Korea National Nutrition Survey, conducted from 1969 until 1995, and the later KNHNS of 1998 and 2001 provided the trend data (figures 1.5 and 1.6) for this study. The KNHNS of 1998 and 2001 are also used to investigate the study questions. For each year, two surveys were conducted during November and December. The KNHNS conducted in 1998 is different from the national nutrition surveys conducted prior to 1995 in several aspects. The KNHNS created under South Korea's National Health Promotion Act 16 is a nationwide survey with a stratified multistage probability sampling design conducted at 3-year intervals, starting in 1998; it combines the national nutrition survey and the national health interview survey. The Korea Institute for Health and Social Affairs and the Korea Health Industry Development Institute conduct the survey under the Ministry of Health and Welfare. The survey consists of four parts: the health interview survey (HIS), the health examination survey (HES), the health behavior survey (HBS), and the nutrition survey (NS). The sample sizes of the HIS in 1998 and 2001 were 13,523 and 13,200 households, respectively. The other three surveys (HES, HBS, and NS) were conducted on a sub-sample of households that completed the HIS. The sample size and response rates of the two surveys are shown in Table 3.1. The NS measured food intake at an individual level by the 24-hour recall method, whereas the previous surveys estimated food consumption by a weighing method at the household level. All households were visited and individuals were interviewed by well-trained health specialists. All physical and biochemical and anthropometric measures were measured at each local station by well-trained specialists.

3.1.2. Sampling population

For the present study, information on all three subsets (HES, HBS and NS) of the surveys was necessary. Among the combined samples of 1998 and 2001, subjects who finished all these HES, HBS and NS were 16,315. Among them, 12,704 were over 18 years old. To exclude subjects who underreported or overreported dietary energy intake, 1271 subjects with energy intake below 0.65×basal metabolic rate (BMR) (lowest 5%) and over 2.45×BMR (highest 5%) were eliminated. Subjects for whom income (n=130) and physical exercise information were lacking (n=402) were excluded. Among the remaining 10,901 subjects, 331 with zero income were excluded. Subjects for whom there was insufficient information on other individual or household characteristics were also eliminated for the final analyses (n=140). Thus, a total of 10,430 adult Koreans were finally considered eligible for this study.

In this study, WHR was used as a proxy of obesity. Thus, although children and adolescents were included in the sampling population, the prevalence of overweight and obesity in children and adolescents was only analyzed to look at whether the prevalence had changed between 1998 and

Table 3.1 The sample size and response rates of the Korea National Health and Nutrition Surveys of 1998 and 2001

	1998		
Survey	Targeted, n	Completed, n	Response rate, %
Health interview	13,523[1]	12,283[1]	90.83
Health behavior	11,289	10,808	95.74
Heath examination	10,876	9,771	89.84
Nutrition	12,074	11,613	96.19
	2001		
Health interview	13,200[1]	12,183[1]	92.30
Health behavior	10,368	9,170	88.45
Heath examination	12,647	9,770	77.25
Nutrition	12,441	10,051	80.79

[1] Number of households

2001. In the analyses, children and adolescents between two and 18 years old who finished the HES were included (n=4029).

3.2. Variables and data sources

3.2.1. Independent variables

3.2.1.1. Individual level

The individual level data from the KNHNS included: gender (male and female), age (years), per capita household income, occupation (legislators, senior officials, and managers; professionals; technicians and associate professionals; clerks; service and sales workers; skilled agricultural, forestry, and fishery workers; craft and related trades workers; plant, machine operators, and assemblers; elementary occupations; armed forces; and unemployed); education (none and illiteracy; none and literacy; elementary school; middle school; high school; college; and graduate school), and marital status (single; married; and widowed, divorced, or separated). Diseases related to dietary intake (diabetes; cancer; and gastrointestinal diseases) and physical activity (respiratory; circulatory; and bone diseases) were also included.

Three variables were predicted because of endogeneity: per capita household income, the probability of regular physical exercise, and dietary energy or fat intake. Per capita household income (10,000 Korean *won*) was predicted based on characteristics of the household head. To predict income, several issues were raised in analyses. The unemployed group was divided into two subgroups: the unemployed heads of household had income from other sources; and unemployed heads of household did not earn income at all (n=331). Due to the large number of zero values, income was not fundamentally normally distributed. The distribution of income was skewed to the right as expected, so it needed to be log-transformed. The log-transformation, however, could not be applied to zero values. Adding a constant, such as 1, to all values in the dataset or setting all the 0 values to 1 is usually used to solve the problem. In this analysis, data were not amenable to either method since neither solved the basic problem of distribution due to the large number of zero values. Thus, unemployed heads of household with zero income were not included. Therefore, the predicted income might be higher than the national average. The income was deflated by the consumer price index (year 2000=1). Food insecurity was measured by questioning whether a subject skipped meals due to lack of financial resources.

There are three components of energy expenditure: basal metabolic rate (BMR), physical activity, and thermogenesis. Energy expenditure is a function of age, sex, weight and height, genetics, and nutritional status. BMR is necessary for body functioning and is a major component of energy expenditure (60-75%). BMR is positively correlated with weight. Physical activity composes 30% of the energy expenditure for people engaging in moderate activity. This varies with kinds and strengths of activity and time duration, and shows the most variations among the three components of energy expenditure. There are two components of thermogenesis, i.e., diet-induced and adaptive thermogenesis. Diet-induced thermogenesis is responsible for 5-10% of the total energy expenditure. Adaptive thermogenesis is not yet well understood. In this study, whether one is doing physical exercise regularly was predicted as a proxy of individual physical activity.

The individual daily caloric intake (kcal) and fat intake (g) were measured by the 24-hr recall method. By the cross-sectional data of this study, however, the causal direction of dietary intake and overweight or obesity was not clear. Usually, people who have a higher BMR eat more than those who have lower BMR. In this study, we want to know, after controlling for this fact, whether higher dietary intake increases overweight or obesity. To control for this, the individual BMR was included in the prediction of dietary intake. BMR was defined by individual age, gender, and weight as shown in Table 3.2. Therefore, separate variables of age and gender were not included in the prediction of dietary intake. BMR is positively correlated with weight. The South Korean Nutrition Society has recommended a daily energy intake based on BMR and physical activity levels accepted by WHO (1985). The predicted daily BMRs is based on the WHO recommendation (1985) and South Korean data as given in Table 3.3.

3.2.1.2. Household level

The individual level data from the KNHNS were the number of household members (n), proportion of dependents in the household (number of dependents divided by total number of household members), and the residential location (urban; suburban; and rural). Changes in prices and income are not the only factors influencing the household demand for goods and services. The two most powerful factors, family size, and composition, have effects on household demand and preferences for goods and services (Bryant 1990, p.73). Numbers of household members were included as a proxy of household size. Dependents meant any members of the household without income sources. Other members' dependency on the head of the household was measured as a proxy of household composition. The residential location

Table 3.2. Equations for BMR by age and sex in South Koreans (kcal/day)

Age (year)	Male	Female
10-19	(17.5×weight)+651	(12.2×weight)+746
20-29	(15.3×weight)+679	(14.7×weight)+496
30-49	(20.4×weight)+302	(15.2×weight)+499
50-64	(18.7×weight)+258	(13.9×weight)+596
65-74	(15.3×weight)+410	(12.3×weight)+539

was an indicator to explain the degree of urbanization experience of the household.

3.2.1.3. Community level

The community where each subject lives was divided by the district in which the subject was physically living. The community level variables from the KNHNS were a proxy for each community's economic and occupational structures (proportion of skilled agricultural, forestry, and fishery workers of the community; proportion of elementary workers of the community; average per capita income in 10,000 Korean *won*); and health prevention behaviors (proportion of people who received health examinations and proportion of people who received education after health examinations).

Another community variable, access to physical exercise, was intended to measure whether a community had a sports complex, a swimming pool, an exercise hall, a tennis court, an indoor golf facility, a physical training center, and/or an aerobic facility. The data were based on the annual reports from each province. There were 241 sub-areas having physical exercise facilities.

Price data were obtained from the National Statistical Office. Prices in Korean *won* for each year and month were deflated by the consumer price index based on the price in 2000. Prices of food commodities (rice, wheat, bread, instant noodles, imported beef, domestic beef, pork, poultry, eggs, bean curd, delivered milk, orange juice, bananas, apples, tangerines, soda, coke, corn oil, soybean oil, snack food, pizza, hamburgers, Soju (Korean traditional liquor), and sugar) and physical exercise (monthly lesson fee for aerobics, monthly entrance fee for golf, and entrance fee for swimming) were included in the analyses. Price variables were selected based on the contribution of each food commodity to daily caloric or fat intake. The correlations between price variables were also considered for the choice of variables. For example, high fat content food such as soybean oil was selected first and other foods were selected by their contribution, with consideration of correlation between variables. Rice and sugar, which contributed to high caloric intake but not fat intake, were not included in the prediction of fat intake.

South Korea has seven main cities (Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, and Ulsan) and eight provinces including smaller cities. The provinces are: Gyeonggi-do (Suwon, Sungnam, Uijeongbu, Anyang, Bucheon, and Goyang); Gangwon-do (Chuncheon, Wonju, and Gangneung); Chungcheongbuk-do (Cheongju and Chungju); Chungcheongnam-do (Cheonan, Gongju, and Boryeong); Jeollabuk-do (Jeonju, Gunsan, and Namwon); Jeollanam-do (Mokpo, Yeosu, and Suncheon); Gyeongsangbuk-do (Pohang, Gyeongju, Andong, and Gumi); Gyeongsangnam-do (Changwon, Masan, and Jinju); and Jeju-do (Jeju and Seogwipo). Price data were based on these locations. Each city is composed of villages and each village has districts. Community variables other than prices were based on the districts in which subjects were living.

3.2.1.4. National level

The time-series data from 1975 to 2005 at the national level were used to investigate the long-term effects of prices on energy or fat intake and BMI. BMI values in the analyses were based on the national average for adults by gender. Per capita daily energy or fat intake was based on the national average and measured in the national nutrition surveys. Prices of each food group or individual food x at time t (rice, instant noodles, domestic beef, pork, poultry, vegetable oil, soda, Soju [Korean traditional liquor], and sugar) were based on the actual price data deflated by the CPI from the Korean National Statistical Office. Per capita gross national income (U.S. dollar) at time t was obtained from the Korea Bank. Urbanization was the percentage of the total population living in an urban environment at time t based on the UNDP Human Development Report and the World Bank World Development Indicators.

3.2.2. Dependent variables

3.2.2.1. Waist-hip ratio (WHR)

WHR is calculated by waist circumferences divided by hip circumferences. In this study, to test the direction of dietary intake and individual heaviness, after including the BMR, body mass index (BMI) was first included as a dependent variable in the analysis, and it proved statistically significant. That is, after controlling for the BMI, the dependent variable in the analysis still influenced dietary intake. In other words, people ate more because they weighed more, which was the opposite of my study question as to whether people weighed more because they ate more. Therefore, BMI proved not to be a good indicator of overweight or obesity in this study. When WHR was included as a predictor, BMR was not statistically significant. WHR instead of BMI was used as an indicator of overweight or obesity in this study.

3.2.2.2. Body Mass Index (kg/m^2)

There are two issues in the use of BMI for predicting overweight and obesity. First, BMI is used worldwide as a surrogate for obesity because of its convenience. As mentioned previously, the rationale of the original BMI cutoffs is the mortality data of Western male populations. In Asian countries, lack of reliable cohort data limits investigation of the relation between mortality and BMI or other indicators.

There are some studies that have looked at the relations between morbidity or disease risk-factors and BMI or other indicators. Thus, the South Korean population might or might not have height-weight relationships and distribution different from those in Western countries. Recent studies have shown that Asians have a lower BMI but a higher percentage of body fat than Caucasians and have a different fat distribution from them. According to Wang *et al*. (1994), Asians had more upper body subcutaneous fat than did whites. Asian populations also have a higher percent of body fat for a given BMI (Deurenberg *et al*. 2002; Deurenberg *et al*. 2003; Guricci *et al*. 1998; He *et al*. 2001). Shiwaku *et al*. (2003) showed that overweight Japanese (BMI 23.0-24.9) exhibited significant differences from normal Japanese (BMI 18.5-22.9) in systolic blood pressure, HDL-cholesterol, and triglycerides in men, and in systolic and diastolic blood pressure, HDL-cholesterol, triglycerides, insulin, and Homeostasis model assessment-insulin resistance in women. However, the results of the study also show that the WHO criteria are more suitable for Mongolians, among whom overweight and normal subjects exhibit no significant differences in metabolic parameters based on the criteria of World Health Organization Western Pacific Region (WPRO). One study in South Korea by Moon *et al*. (2002) showed that both hypertension and diabetes mellitus occurred in Koreans with lower BMIs than whites by using data obtained from the National Health Interview Survey. The risk of hypertension and diabetes mellitus increased at the third quartile of BMI (21.9-23.8), which is not significantly different from the odds ratio of the fourth quartile (>23.8) and is lower than the current WHO BMI cutoff point for overweight of 25.0. However, self-reported weights and heights and lack of biomedical indicators such as body fat composition limit this study. In Asians, obesity-related diseases seem to occur at a lower BMI (ECC 2002; Pan *et al*. 2004; Ohmura *et al*. 1993; Tokunaga *et al*. 1991) but the evidence is not sufficient to change current cutoffs.

Although revisions of BMI cutoffs for defining overweight and obesity are controversial (Misra 2003; Pan *et al*. 2004; Stevens 2003a; Stevens 2003b), the Regional Office of the Western Pacific Region of WHO, the International Association for the Study of Obesity, and the International Obesity Task Force (2000) proposed a separate classification of obesity for Asia in 2000. They recommended the new criteria that adult overweight be specified in Asians as a BMI≥23.0 and that obesity be specified as a BMI ≥ 25.0 (WPRO criteria). Second, despite wide acceptance of the BMI to establish overweight and obesity, some researchers reported that waist circumference (WC) is more closely linked to visceral fat (Janssen *et al*. 2002), total body fat (Lean, Han, Deurenberg 1996), and disease risk factors (Janssen, Katzmarzyk, Ross 2004; Lean, Han 2002; Wang 2003; Zhu *et al*. 2002) and is a convenient and cost-effective measure of abdominal adipose tissue (Han *et al*. 1995; Pouliot *et al*, 1994; Ross *et al*. 1992). Others, however, reported that, although the WC may improve the criteria for assessing risk at any given BMI, there is not yet sufficient evidence for replacing BMI with WC (Bray 2004). In another study, it was found that BMI, WC, and WHR can all identify overweight and obesity (Gill *et al*. 2003).

Although there are various definitions of childhood overweight or obesity in use, little consensus has been reached to date. Weight adjusted for height has been used to assess the prevalence of underweight, overweight, and obesity in children for several years. In the past, weight-for-height was used as a simple index independent of age (Waterlow 1972); recently, BMI adjusted for age has been more widely used to assess the prevalence of childhood obesity (Cole, Freeman, Preece 1995; Dietz, Robinson 1998). The BMI suitable for children and adolescents need to be calculated and plotted on the BMI percentile chart (Cole 2002; He, Albertsson-Wikland, Karlberg 2000;Ogden, Kuczmarski, Flegal 2002). The 85^{th} and 95^{th} percentiles of BMI by age, have been designated as international standard cutoffs to define overweight and obesity in children based on nationally representative survey data in the U.S. (Barlow, Dietz 1998; Kuczmarski *et al*. 2000). More recently, Cole *et al.* (2000) defined international cutoffs of overweight and obesity for boys and girls aged two to 18 using both these criteria and nationally representative data from Brazil, the U.K., Hong Kong, the Netherlands, Singapore, and the U.S., the cutoffs corresponding to BMI of 25.0 and 30.0 kg/m^2 in adults.

To construct percentile curves for BMI at each age and to determine the BMI cutoffs for underweight, overweight, and obesity, Cole *et al*. (2000) used the modified LMS method (Kuczmarski *et al*. 2002), which involves obtaining the lambda (L), median (M), and coefficient of variation (S) for the BMI at each age. After smoothing the BMI percentile at each age, an LMS inversion equation was derived from the smoothed BMI. L, M, and S values were inferred for each age by the SAS NLIN procedure, which minimizes the sum of squared errors of empirical percentiles. In this derivation, the BMI values were used as a continuous variable. The Z scores corresponding to percentiles were as follows: 3rd percentile, –1.881; 5th percentile, –1.6451; 10th percentile, –1.282; 15th percentile, –1.036; 25th percentile, –0.674; 50th percentile, 0.0; 75th percentile, 0.674; 85th percentile, 1.036; 90th percentile, 1.282; 95th percentile, 1.645; and 97th percentile, 1.881. The LMS inversion equations were:

$C100\alpha(t)=M(t)[1+L(t)S(t)Z\alpha]^{1/L(t)}$ $\quad\quad$ $L(t) \neq 0$

$C100\alpha(t)=M(t)Exp[S(t)Z\alpha]$ $\quad\quad$ $L(t) = 0$

Using these LMS inversion equations, I will fit each percentile for each age. It should be noted that the BMI values of 18.5, 23.0, and 25.0 kg/m^2 or 18.5, 25.0, and 30.0 kg/m^2 at age 18 correspond to those for underweight, overweight, and obesity, which were previously proposed by IOTF and WHO. The Z scores corresponding to these BMI values at age 18 are then calculated from the L, M, and S values at age 18, with the formula:

$Z\alpha=[(BMI(t)/M(t))^{L(t)}-1]/L(t)S(t)$

Each Z score will be substituted into the LMS inversion equation above to provide the formula for an extra percentile curve passing through the specified points.

This statistical analysis will be performed using the SAS program (SAS Institute Inc., Cary, NC, USA Release 8.1). I will use the LOESS procedure for smoothing the percentiles of BMI for ages two to 18 and the SAS NLIN procedure for inferring L, M, and S values.

The cutoffs are shown in Tables 3.3 and 3.4. Based on the cutoffs, the overweight increased by 0.8% in boys and 1.2 in girls respectively from1998 to 2001. Interestingly, the prevalence of obesity increased by 4.52% in boys but decreased by 0.15% in girls (Table 3.5).

Table 3.3 BMI cutoffs for underweight, overweight, and obesity for South Korean boys and girls between two and 18 years from the survey in 1998, defined to pass through BMI of 18.5, 23.0, 25.0, and 30.0 kg/m^2 at age 18

	Years	***N***	**18.5**	**23.0**	**25.0**	**30.0**
Boys	18	80	18.50	23.00	25.00	30.00
	17	97	18.06	22.37	24.39	29.75
	16	120	17.62	21.77	23.80	29.60
	15	96	17.18	21.17	23.22	29.52
	14	85	16.72	20.57	22.64	29.49
	13	96	16.31	20.15	22.23	29.21
	12	82	15.92	19.74	21.82	28.92
	11	100	15.53	19.34	21.42	28.59
	10	97	15.14	18.94	21.02	28.19
Girls	18	95	18.50	23.00	25.00	30.00
	17	103	18.24	22.73	24.70	29.55
	16	113	17.95	22.44	24.40	29.17
	15	92	17.66	22.15	24.10	28.84
	14	79	17.26	21.81	23.75	28.37
	13	88	16.76	21.30	23.34	28.45
	12	82	16.26	20.79	22.93	28.66
	11	70	15.76	20.28	22.52	28.98
	10	79	15.26	19.76	22.10	29.39

Table 3.4 BMI cutoffs for underweight, overweight, and obesity for South Korean boys and girls between 2 and 18 years from the survey in 2001, defined to pass through BMI of 18.5, 23.0, 25.0, and 30.0 kg/m^2 at age 18

	Years	***N***	**18.5**	**23.0**	**25.0**	**30.0**
Boys	18	54	18.50	23.00	25.00	30.00
	17	58	18.25	22.81	24.76	29.46
	16	63	18.00	22.62	24.53	28.91
	15	80	17.76	22.44	24.49	28.35
	14	76	17.45	22.11	23.91	27.75
	13	101	17.06	21.74	23.51	27.18
	12	76	16.63	21.27	22.99	26.51
	11	104	16.17	20.61	22.25	25.63
	10	86	15.68	19.83	21.39	24.64
	9	144	15.23	18.96	20.41	23.53
	8	101	14.83	18.09	19.42	22.42
	7	95	14.55	17.32	18.52	21.47
	6	99	14.38	16.75	17.83	20.65
	5	92	14.32	16.43	17.40	20.03
	4	103	14.35	16.46	17.38	19.66
	3	90	14.41	16.57	17.42	19.28
	2	71	14.52	16.82	17.54	18.87
Girls	18	51	18.50	23.00	25.00	30.00
	17	71	18.13	22.66	24.68	29.74
	16	65	17.75	22.33	24.37	29.48
	15	69	17.36	21.97	24.03	29.17
	14	70	16.96	21.63	23.74	29.08
	13	78	16.53	21.28	23.47	29.15
	12	79	16.10	20.85	23.09	29.09
	11	78	15.64	20.15	22.33	28.33
	10	83	15.19	19.24	21.28	27.23
	9	106	14.84	18.32	20.17	26.10
	8	73	14.52	17.57	19.27	25.25
	7	91	14.36	17.05	18.63	25.10
	6	98	14.23	16.70	18.18	24.56
	5	91	14.19	16.55	17.89	23.02
	4	98	14.17	16.54	17.74	21.35
	3	62	14.16	16.60	17.63	20.09
	2	66	14.20	16.67	17.51	19.17

Table 3.5 Distribution of BMI among South Korean boys and girls (%)

	N	**<18.5**	**18.5-22.99**	**23.00-24.99**	**25.00-29.99**	**30.00-**
1998 Male	853	10.67	59.20	14.42	14.54	1.17
1998 Female	354	14.11	63.05	11.11	10.99	0.75
2001 Male	1493	13.26	52.71	12.99	15.34	5.69
2001 Female	1329	10.76	56.51	19.94	12.19	0.60

Values are percentages of boys and girls in each year corresponding to BMI of 18.5, 23.0, 25.0, 30.0 kg/m^2 at age 18

3.3. Data analysis

Standard statistical methods will be used to examine the distribution of each variable. If continuous variables are dependent variables in a regression analysis and their distribution deviates substantially from the normal distribution, they will be transformed by the logarithm or other relevant functions. The large sample size for the KNHNS data in 1998 and 2001 provides statistical power adequate to identification of even small differences at each time point. Time series data will make plausible causal inferences using dynamic models. Dynamic models capture the effects of independent variables on changes (if continuous) or transitions (if binary) in the dependent variables. The possible problem of autocorrelations will be tested. This will be discussed later. All analyses will be implemented in the SAS version 8.1.

3.4. Modeling

3.4.1. The cross-sectional data

The modeling will be guided by the conceptual framework outlined earlier as shown in Figure 1.9. Models (1) and (2) are the full model of this study.

$$O = f(A, A^2, G, E, J, M, \hat{I}, \hat{I}^2, \hat{P}, \hat{C}, \hat{C}^2, DD, CD, GD, RD, CD, BD, L, PA, PE, AI, PH, PE) \quad -(1)$$

O represents obesity measured by WHR. A and A^2 indicate each subject's age and its square. G, E, J, and M represent each subject's gender, education level, occupation, and marital status, respectively. $\hat{I}$ and $\hat{I}^2$ are the predicted per capita household income and its square. $\hat{P}$ is the predicted probability of whether a subject does physical exercise. $\hat{C}$ and $\hat{C}^2$ are the predicted energy intake of each subject and its square. DD, CD, GD, RD, LD, and BD represent whether a subject has diabetes, cancer, gastrointestinal diseases, respiratory diseases, circulatory diseases, and bone diseases, respectively. L is the residential location of the household. PA is the proportion of skilled agricultural, forestry, and fishery workers in the community. PE is the proportion of elementary workers in the community. AI represents the community average of per capita income. PH indicates the proportion of people in the community who received health examinations. PE is the proportion of people in the community who received education after health examinations.

$$O = f(A, A^2, G, E, J, M, \hat{I}, \hat{I}^2, \hat{P}, \hat{F}, \hat{F}^2, DD, CD, GD, RD, CD, BD, L, PA, PE, AI, PH, PE) \quad \text{–(2)}$$

Model (2) has the same predictors as Model (1) except that fat intake is included instead of energy intake. $\hat{F}$ and $\hat{F}^2$ are the predicted fat intake of each subject and its square.

Income is known to be an endogenous variable. Most studies have reported the independent effects of diet and physical activity on overweight or obesity. Some, however, suggest that they are correlated, i.e., the more a person engage in exercise, the more a person eats. Therefore, the relation between energy intake and energy expenditure needs to be investigated if there is any possibility of the endogeneous problem. Thus, income, probability of doing physical exercise, and dietary intake were predicted as follows:

$$I = f(HA, HA^2, HG, HE, HJ, HM, HH, N, D, PA, PE, AI) \quad \text{–(3)}$$

The characteristics of the head of household were used to predict income in Model (3). I represents per capita household monthly income. HA and HA^2 indicate the household head’s age and its square. HG, HE, HJ, HM, and HH represent the household head’s gender, education level, occupation, marital status, and health status, respectively. N represents the number of household members. D is the proportion of dependents in the household.

The probability of doing physical exercise was predicted as follows:

$P = f(A, A^2, G, E, J, M, \hat{I}, \hat{I}^2, PF_g, PP_g, LD, RD, BD, N, D, L, PA, PE, AI, PH, PE)$ –(4)

PF_g represents the group of variables of access to physical activity facilities, including a sports complex, swimming pool, exercise hall, tennis courts, indoor golf center, physical training center, and aerobics. PP_g represents the group of variables of prices of physical activity including golf, aerobics, and swimming.

The energy and fat intakes were predicted as in Model (5) and (6). C and F represent daily energy intake in kilocalories and fat intake in grams.

$C = f(B, E, J, M, \hat{I}, \hat{I}^2, S, FF_g, DD, CD, GD, N, D, L, PA, PE, AI, PH, PE)$ –(5)

$F = f(B, E, J, M, \hat{I}, \hat{I}^2, S, FF_g, DD, CD, GD, N, D, L, PA, PE, AI, PH, PE)$ –(6)

B represents individual basal metabolic rate based on age, sex, and weight. S indicates food security measured by a question of whether one skips meals due to lack of financial resources. FF_g represents the group of variables of food prices.

To compare the relative importance between income and dietary intake, the full model was tested without dietary intake variables:

$O = f(A, A^2, G, E, J, M, \hat{I}, \hat{I}^2, \hat{P}, DD, CD, GD, RD, CD, BD, L, PA, PE, AI, PH, PE)$ –(7)

and without income variables:

O=f (A, A^2, G, E, J, M, $\hat{P}, \hat{C}, \hat{C}^2$, DD, CD, GD, RD, CD, BD, L, PA, PE, AI, PH, PE) –(8)

O=f (A, A^2, G, E, J, M, $\hat{P}, \hat{F}, \hat{F}^2$, DD, CD, GD, RD, CD, BD, L, PA, PE, AI, PH, PE) –(9)

The direct impact of prices on obesity was also tested by a replacement of dietary intake by selected price variables:

O=f (A, A^2, G, E, B, J, M, $\hat{I}$, $\hat{I}^2, \hat{P}$, FF_g, DD, CD, GD, RD, CD, BD, L, PA, PE, AI, PH, PE) –(10)

The basal metabolic rate was included to control individual basic needs for food consumption based on age, gender, and weight.

The full model, (1), can be modified by the genetic factors of individuals.

O=f (A, A^2, G, E, J, M, $\hat{I}$, $\hat{I}^2, \hat{P}, \hat{C}, \hat{C}^2$, N, DD, CD, GD, RD, CD, BD, L, PA, PE, AI, PH, PE) –(11)

N indicates the individual genetic characteristics. Usually, mothers influence children's lifestyles more than fathers, and comparing mother's and father's status might suggest relative effects. By using separate variables for mothers and fathers, one can test whether the parents' effects are additive or multiplicative. If there is an interaction between maternal and paternal effects on child obesity, the parents' effects are multiplicative rather than additive. This can be simply tested with the model below:

$$\text{logit (O)}_i = \beta_0 + \beta_1(FO)_i + \beta_2(MO)_i + a_3(FO \times MO) \text{ -(12)}$$

Where, FO=1 if a father is obese; =0 otherwise

MO=1 if a mother is obese; =0 otherwise

The result would be an odds ratio. The nature of surveys, however, is not appropriate to test this. First, surveys do not include any specific genetic information for such a test. Second, it is difficult to employ proxies such as a family history of obesity because the studies do not distinguish between biological parents and stepparents and family history has both environmental and genetic effects on obesity.

3.4.2. The longitudinal data

To investigate the long-run effects of overweight or obesity, longitudinal data were used in the analyses. Per capita energy and fat intakes were predicted as below in Models (13) and (14).

$$C_t = f(U_t, G_t, FPg_t) \text{ -(13)}$$

$$F_t = f(U_t, G_t, FPg_t) \text{ -(14)}$$

where, C_t and F_t represent per capita energy and fat intakes each year. U_t and G_t indicate the percentages of urbanization and gross national income at time t. FPg_t represents the group of food commodity prices at time t. The direct effects of food prices on obesity were also tested in Model (15) by gender.

$$Ob_t = f(U_t, G_t, FPg_t) \text{ -(15)}$$

Ob_t represents the mean value of average values of BMI at time t.

3.4.3. Price elasticities

The price elasticities of energy and fat intakes with respect to the price of food commodities is defined as in Equations (16) and (17) in the cross-sectional data.

$$\varepsilon_{Ep} = \frac{\Delta E}{\Delta P} \cdot \frac{\overline{P}}{\overline{E}} \text{ -(16)}$$

$$\varepsilon_{Fp} = \frac{\Delta F}{\Delta P} \cdot \frac{\overline{P}}{\overline{F}} \text{ -(17)}$$

where, $\varepsilon_{\mathrm{EP}}$ and $\varepsilon_{\mathrm{FP}}$ represent the price elasticity of energy and fat intakes with respect to food prices. $\Delta E, \Delta F, and\ \Delta P$ indicate the differences of energy, fat, and food prices between 1998 and 2001. $\overline{E}, \overline{F}, and\ \overline{P}$ represent the average values of energy, fat, and food prices between 1998 and 2001. $\Delta E / \Delta P$ in (16) and $\Delta F / \Delta P$ in (17) are β coefficients from the regression analyses of (1) and (2). Thus, price elasticities can be calculated by multiplying the ratio of average values of price to energy or fat intake, i.e.,

$$\varepsilon_{EP} = \beta \times \overline{P} / \overline{E} \text{ -(18)}$$

$$\varepsilon_{FP} = \beta \times \overline{P} / \overline{F} \text{ -(19)}$$

In the time-series data, price elasticities for energy and fat intake with respect to the food commodity prices are the coefficients of regression analyses in (13) and (14) since price and intake variables were log-transformed in those models.

Price elasticities of WHR in the cross-sectional data can be obtained from the reduced Model (10).

$$\varepsilon_{\mathrm{OP}} = \frac{\Delta O}{\Delta P} \cdot \frac{\overline{P}}{\overline{\mathrm{O}}} \text{ -(20)}$$

where, $\varepsilon_{\mathrm{OP}}$ represents the price elasticity of WHR with respect to food prices. ΔO indicates the differences of WHR between 1998 and 2001. $\overline{O}$ represents the average values of WHR between 1998 and 2001. $\Delta O / \Delta P$ in (20) is a coefficient from the regression analyses of (10). Thus, price elasticities can be calculated by multiplying the ratio of average values of price to WHR, i.e.,

$$\varepsilon_{OP} = \beta \times \overline{P} / \overline{O} \text{ -(21)}$$

There is another way to calculate price elasticities of WHR with respect to the food prices based on the full models of (1) and (2). The elasticities of WHR with respect to the energy and fat intakes are as in equations (22) and (23).

$$\varepsilon_{\mathrm{OC}} = \frac{\Delta O}{\Delta C} \cdot \frac{\overline{C}}{\overline{\overline{\mathrm{O}}}} \text{-(22)}$$

$$\varepsilon_{\mathrm{OF}} = \frac{\Delta O}{\Delta F} \cdot \frac{\overline{F}}{\overline{\overline{\mathrm{O}}}} \text{-(23)}$$

where, $\varepsilon_{\mathrm{OC}}$ and $\varepsilon_{\mathrm{OF}}$ represent the elasticities of WHR with respect to the energy and fat intake, respectively. Price elasticities for energy and fat intake with respect to the food commodity prices, i.e., $\varepsilon_{\mathrm{CP}}$ and $\varepsilon_{\mathrm{FP}}$ can be obtained From Models (13) and (14) of the time-series data. Then, by combining these with the elasticities from (22) and (23), the elasticities of WHR with respect to the food commodity prices can be calculated as below.

$$\varepsilon_{\mathrm{OP}} = \frac{\Delta O}{\Delta P} \cdot \frac{\overline{P}}{\overline{\overline{O}}} = \frac{\Delta O}{\Delta P} \cdot \frac{\overline{P}}{\overline{\overline{\mathrm{O}}}} \cdot \frac{\Delta C}{\Delta C} \cdot \frac{\overline{C}}{\overline{\overline{C}}} = \left(\frac{\Delta C}{\Delta P} \cdot \frac{\overline{P}}{\overline{\overline{C}}} \right) \cdot \left(\frac{\Delta O}{\Delta C} \cdot \frac{\overline{C}}{\overline{\overline{O}}} \right) = \varepsilon_{CP} \cdot \varepsilon_{OC} \text{-(24)}$$

$$\varepsilon_{\mathrm{OP}} = \frac{\Delta O}{\Delta P} \cdot \frac{\overline{P}}{\overline{\overline{O}}} = \frac{\Delta O}{\Delta P} \cdot \frac{\overline{P}}{\overline{\overline{\mathrm{O}}}} \cdot \frac{\Delta F}{\Delta F} \cdot \frac{\overline{F}}{\overline{\overline{F}}} = \left(\frac{\Delta F}{\Delta P} \cdot \frac{\overline{P}}{\overline{\overline{F}}} \right) \cdot \left(\frac{\Delta O}{\Delta F} \cdot \frac{\overline{F}}{\overline{\overline{O}}} \right) = \varepsilon_{FP} \cdot \varepsilon_{OF} \text{-(25)}$$

where, $\varepsilon_{\mathrm{OP}}$ represents the price elasticities of WHR with respect to the food commodity prices. In the time-series data, price elasticities for BMI are the coefficients of regression analyses in (15) since price and BMI variables were log-transformed in the model.

3.4.4. The magnitude of effects

The magnitude of effects of WHR or BMI due to the price changes between 1998 and 2001, i.e., ΔP, can be calculated by equations (26) and (27):

$$\Delta O = \varepsilon_{\mathrm{OP}} \cdot \overline{O} / \overline{P} \cdot \Delta P \quad \text{-(26)}$$

$$\Delta Ob = \varepsilon_{\mathrm{ObP}} \cdot \overline{O} b / \overline{P} \cdot \Delta P \text{-(27)}$$

To make a rough estimation of how much waist circumferences and body weight changed during the period of 1998 and 2001, hip circumferences of 100 cm and heights of 170 cm for males and 160 cm for females were used.

3.5. Statistical issues

3.5.1. Cross-sectional and longitudinal aspects of the survey

The data from the two national surveys in 1998 and 2001 are cross-sectional. Important exceptions, however, are the anthropometric measures (especially weight and waist circumference), which reflect the accumulated effect of determinants such as diet and physical activity over time and which therefore have a longitudinal nature. A question about weight or waist circumference change as well as food consumption patterns during the previous year in both surveys can be useful for looking at this longitudinal factor of anthropometry.

One might raise the issue of potential recall bias or of the uncertainty of the necessary assumption that determinants measured today are associated with what happened in the past. To minimize these issues, well-trained interview specialists were trained before the onset of the surveys. In addition, I employ time-series economic data from 1975 to 2005. The data are largely from several sections of South Korean government institutions. Later, the results of time-series analyses will be linked to cross-sectional analyses.

3.5.2. Heteroscedasticity

One of the assumptions in ordinary least square (OLS) models is that the disturbances have uniform variances. If this assumption is violated, the OLS estimator is not longer efficient (Gujarati 2001). One could expect the variance to appear with subjects who do not manage weight well enough, e.g., do not balance dietary intake and physical activity. To explore the possibility of heteroscedasticity, adults fitting supposedly ideally shaped reference curves, a high energy intake group, and a low energy intake group are compared as regards WHR. Similarly, adults of supposedly ideally shaped reference curves, a high physical activity group, and a low physical activity group are compared on WHR. These comparisons will indicate whether there is any consistent difference in the variance of each group as compared to the ideal. The uniform disturbance of the error term is examined in the analyses. If the presence of heterosdecasticity is confirmed, appropriate modeling techniques will be employed, i.e., generalized least squares and not OLS (Gujarati 2001).

3.5.3. Endogeneity

When variables are not determined by a single relationship/equation, but coexist with other variables in a system of simultaneous equations, they are called endogeneous (as compared to exogeneous variables, which are determined outside the system of equations and can be called predetermined) (Johnston, DiNardo 1997). Endogeneous variables are correlated with the error term, which means that one of the basic assumptions of OLS for estimating the regression coefficients is violated. Consequently, using OLS will lead to biased and inconsistent regression estimates (Gujarati 2001).

The problem of endogeneity may seem related to the epidemiological concept of reverse causation (Habicht *et al*. 1986), but it is different. The concept of reverse causation assumes that there is only one true causal direction, which can be identified by taking confounders into account (e.g., adding relevant confounders to the model or avoiding selectivity bias). In models with endogeneous variables, unidirectional causality is not assumed. The main characteristic and quality of the concept of endogeneity (and its econometric solutions) is that it allows variables to be simultaneously determined. This means that bidirectional causality is possible and allowed, and that the focus shifts to estimating the true coefficients for each direction properly. This can be done with instrumental variables. Many authors have described the problem of ignoring endogeneity in epidemiological studies (Briscoe *et al*. 1990; Zohoori, Savitz 1997), however, the number of studies in the field of nutritional epidemiology recognizing the problem and employing appropriate modeling techniques to take care of it remains very small.

In the case of endogeneity, the instrumental variable can be used to produce consistent estimators. In order to use the instrumental variable estimator, one must find an instrument for each endogeneous variable. This is a new independent variable with two necessary characteristics: first, it must be contemporaneously uncorrelated with the error term and, second, it must be correlated with the regressor for which it is to serve as an instrument. The major disadvantage of the instrumental variable is that the variance-covariance matrix of the instrumental variable estimator is larger than that of the OLS estimator, leading to less precise estimates (Gujarati 2001).

Therefore, deciding on whether to use the instrumental variable procedure depends on what it is more relevant to the researcher, accuracy or precision. The problem is that, although the direction of the bias can be predicted in most cases, its size remains unknown. The use of the MSE criterion, which takes both variance and bias into account in deciding on the chosen estimator, is also impossible. In this study, income, dietary intake, and the probability of doing physical exercise were considered as endogenous variables. Simultaneous equations were used to predict these variables.

3.5.4. Autocorrelation

The assumption of nonautocorrelation of the classical OLS model relates to population disturbances, which are not directly observable. Thus, residuals are used as their proxies; these can be obtained by the usual OLS procedure. A graphical examination of residuals can provide useful information not only about autocorrelation but also about heteroscedasticity, model inadequacy, or specification bias (Gujarati 2001). The time sequence plot, residuals versus time or standardized residuals (residuals divided by the standard error of the regression) versus time, can be used. If autocorrelation is detected, remedial measures are used. First, one can use appropriate transformation of the original model so that, in the transformed model, the problem of autocorrelation does not occur. As in the case of heteroscedasticity, the GLS method can be employed. Second, in large samples, one can use the Newey-West method to obtain standard errors of OLS estimators that are corrected for antocorrelation (Gujarati 2001).

3.5.5. Effect modification

According to Kelsey *et al*. (1996), effect modification occurs when the magnitude of the chosen measure of association between a causal agent and a disease differs according to the level of a third variable. This means that the magnitude of the association is conditional upon the effect modifier. The epidemiological concept of effect modification and interaction as described in statistics are identical.

CHAPTER 4

RESULTS

4.1. General characteristics of the sample

4.1.1. General characteristics

General characteristics of the studied subjects are shown in Table 1. Among the 10,430 subjects included, 44.42% were men. The mean age of this sample was 44 years, with a range of 18 to 94. The average per capita household monthly income was about 650,000 Korean *won* (around U.S.$650), with a wide range from 19,286 *won* (around U.S.$19) to 6,206,747 *won* (around U.S.$6,200). Fifty-one percent of the subjects were currently working. About 49 percent of them were unemployed. This unemployed group included housewives, people who were retired, students, and the truly unemployed. Over half of the sample graduated from high school. The majority of subjects were married (74.46%). About one third of the sample had bone diseases. The average body mass index (BMI) was 23.28, which meant that the mean value was in the normal category by Western BMI standards and in the overweight one by Asian standards. The mean values of WHR in males and females were 0.89 and 0.84 respectively (data not shown). The average basal metabolic rate (BMR), daily caloric intake, and fat intake were 1,465kcal, 1,976kcal, and 36g, respectively. One third of the sample performed physical exercise.

More than half (56%) of the sample had a household size of three or four people. The mean proportion of dependents in the household was 0.60, meaning that, on average, 40% of household members earned income. Most of the households (70%) were located in urban or suburban areas.

For community variables, the average proportion of skilled agricultural, forestry, and fishery workers in the community was 13% with a range of 0% to 80%. The mean proportion of elementary workers in each community was 5% with a range of 0% to 29%. The community average per capita household monthly income was 630,000 *won* (around U.S.$630). In each community, on average, less than half of the subjects (46%) received health examinations. Among them, on average, 23% received the health education after the examinations.

4.1.2. Variables of physical exercise: price and access

For prediction of the probability of doing physical exercise, variables of access to facilities of physical exercise and fees for them were included. In their residential locations, one half of the sample had a sports complex, 63 percent had tennis courts, and 87 percent had a swimming pool. Most of them had an exercise hall, a physical training center, an indoor golf facility, and an aerobic facility near their home. The average monthly lesson fee for aerobics was 49,930 *won* (around U.S.$50). Using an indoor golf facility cost 224,781 *won* (around U.S.$225) per month on average. The entrance fee for the swimming pool each time cost 4,127 *won* (around U.S.$4) on average.

4.1.3. Prices of food commodities

The prices of food commodities per 100 kcal are shown in Table 4.3. The price of rice, a major staple food in Korea, was 63 *won* (around U.S.$0.06) per 100kcal. The prices of high energy content foods, such as corn oil, soybean oil, and sugar were relatively cheap: 21, 24, and 31 *won* (around U.S. $0.02, 0.02, and 0.03), respectively. The prices of meat were relatively expensive:

Table 4.1 General characteristics of the sample (n=10430)

Characteristics	
Individual	
Male (N (%))	4633 (44.42)
Age (year)	44.23±15.82
Per capita household income (10,000 Korean *won*)	64.65±48.41
Occupations (N (%))	
Legislators, senior officials, & managers	50 (0.48)
Professionals	398 (3.82)
Technicians & associate professionals	294 (2.82)
Clerks	798 (7.65)
Service & sales workers	1325 (12.70)
Skilled agricultural, forestry, & fishery workers	747 (7.16)
Craft & related trades workers	703 (6.74)
Plant, machine operators, & assemblers	369 (3.54)
Elementary occupations	643 (6.16)
Armed forces	17 (0.16)
Unemployed	5086 (48.76)
Education (N (%))	
None, illiteracy	480 (4.60)
None, literacy	549 (5.26)
Elementary school	1738 (16.66)
Middle school	1377 (13.20)
High school	3721 (35.68)
College	2359 (22.62)
Graduate school	206 (1.98)

Table 4.1 (Continued)

Variables	
Individual (continued)	
Marital status (N (%))	
Single	1556 (14.92)
Married	7766 (74.46)
Widowed	933 (8.95)
Divorced/separated	175 (1.68)
Diseases (N (%))	
Diabetes	401 (3.84)
Cancer	57 (0.55)
Gastrointestinal diseases	1107 (10.61)
Respiratory diseases	286 (2.74)
Circulatory diseases	1106 (10.60)
Bone diseases	3219 (30.86)
Body Mass Index (kg/m^2)	
Waist hip ratio (waist/hip)	0.859±0.076
Basal metabolic rate (kcal)	1465.27±230.06
Daily caloric intake (kcal)	1976.48±662.21
Daily fat intake (g)	36.36±27.10
Performing physical exercise (N (%))	3178 (30.47%)

Table 4.1 (Continued)

Variables	
Household	
No. of household members (N (%))	
1	562 (5.39)
2	1897 (18.19)
3	2251 (21.58)
4	3590 (34.42)
5	1394 (13.37)
6	495 (4.75)
7	241 (2.31)
Proportion of dependents	0.60±0.24
Residential location (N (%))	
Urban	4299 (41.22)
Suburban	2817 (27.01)
Rural	3314 (31.77)
Community	
Proportion of skilled agricultural, forestry, & fishery workers	0.131±0.199
Proportion of elementary workers	0.053±0.052
Average per capita income (10,000 Korean *won*)	63.04±26.21
Proportion of people who received health examinations	0.460±0.120
Proportion of people who received education after health examinations	0.232±0.149

Table 4.2 Variables of physical exercise

Variables	
Access to physical exercise (N (%))	
Having a sports complex	5255 (50.38)
Having a swimming pool	9068 (86.94)
Having a exercise hall	10397 (99.68)
Having tennis courts	6570 (62.99)
Having an indoor golf facility	10008 (95.95)
Having a physical training center	10320 (98.95)
Having an aerobic facility	9865 (94.58)
Prices of physical exercise (Korean won)	
Aerobics, monthly lesson fee	49,930.44±8,730.38
Golf, monthly entrance fee	224,781.42±39,120.40
Swimming, per entrance	4,127.40±1,050.42

Table 4.3 Means of prices of food commodities

Food commodity	Korean *won*/100kcal
Rice	63.16282
Wheat	20.0776
Bread	229.4616
Instant noodles	83.4612
Imported beef	512.1519
Domestic beef	1291.191
Pork	252.9329
Poultry	187.0185
Eggs	327.8732
Bean curd	147.4997
Delivered milk	310.0566
Orange juice	635.4522
Bananas	229.0057
Apples	440.6526
Tangerines	229.4616
Soda	177.4821
Coke	190.1225
Corn oil	21.07084
Soybean oil	24.47520
Snack food	82.12734
Pizza	2642.744
Hamburgers	400.2826
Soju (Korean traditional liquor)	146.4128
Sugar	30.71938

prices of Korean domestic beef, imported beef, pork, and poultry were 1,291, 512, 253, and 187 *won* (around U.S.$1.3, 0.5, 0.3, and 0.2), respectively. The price of Korean domestic beef was more than twice that of imported beef. The highest price was that of pizza, 2,143 *won* (around U.S.$2).

4.2. The effects of price, income, community characteristics, dietary intake, and physical activity on waist-hip ratio (WHR)

4.2.1. Income prediction

The income prediction was followed by Model (13) in the previous chapter. As shown in Table 4.4, the model explained 50.79% of the variability. A male household head earned more income than a female one. If the occupation of the household head were legislator, senior official, and manager, professional, or clerk, the household's per capita income was more than that of a household with an unemployed head. If the household head worked as a lower class worker such as skilled agricultural, forestry and, fishery or elementary occupation, the per capita household income was lower than that of a household with an unemployed head. The greater the education of the household head, the higher the per capita household income. But there was no difference between college and graduate school degrees. Single households had a lower income and married households had a higher income than divorced or separated households. The healthier the household head, the higher the per capita income.

Overall, the per capita household income decreased as the number of household members or the proportion of dependents in the household increased. As the proportion of skilled agricultural, forestry, and fishery workers living in the community increased, the per capita household income decreased. The community average per capita income was positively related to that of the household.

4.2.2. Physical exercise prediction

Physical exercise was predicted by Model (4) in the previous chapter. Thirty-one percent of the sample performed physical exercise (N=3187). The average exercise times of the whole sample and the subsample that did physical exercise were 18.56 and 61.18 minutes per week, respectively, with a range of 7 to 210 minutes per week. Among people performing physical exercise, 55 percent exercised less than or equal to 30 minutes per week, 67 percent exercised less than or equal to 60 minutes per week, and 90 percent exercised less than or equal to 120 minutes per week (data not shown).

The results of the statistical analyses are shown in Table 4.5. The income level did not influence the probability of doing physical exercise. If one was living in a community without a physical training center, his or her probability of doing physical exercise was decreased. The relative odds of doing physical exercise without having a physical training center near home relative to having such a center near home were 0.620 (Table 4.6). If monthly fees for aerobic classes or golf entrance fees were increased, people were less likely to do physical exercise (Table 4.5).

Males were 2.075 times more likely to perform physical exercise than their female counterparts (Table 4.6). As age increased, people were more likely to exercise, but after 50.32 years old (by taking derivatives and getting the maximum value of $-0.00062\ \text{age}^2 + 0.0624\ \text{age}$), the probability of doing physical exercise started declining. Legislators, senior officials, managers, professionals, and members of armed forces were more likely to exercise than

Table 4.4 Prediction of household per capita income by characteristics of the household head (n=10430)

Variables	Coefficient	t-values	P-value
Head of household			
Male (female)	0.104349256	5.37	<.0001
Age	0.022324496	7.12	<.0001
Age^2	-0.000355614	-11.14	<.0001
Occupations (unemployed)			
Legislators, senior officials, & managers	0.262060577	5.05	<.0001
Professionals	0.178351983	4.62	<.0001
Technicians & associate professionals	0.061396431	1.58	0.1142
Clerks	0.075713822	2.24	0.0251
Service & sales workers	0.019705472	0.63	0.5279
Skilled agricultural, forestry, & fishery workers	-0.144035840	-4.52	<.0001
Craft & related trade workers	0.060100321	1.80	0.0718
Plant, machine operators, & assemblers	0.032398052	0.91	0.3632
Elementary occupations	-0.219674166	-6.35	<.0001
Armed forces	0.111388081	0.87	0.3836
Education (graduate school)			
None, illiteracy	-0.562642899	-11.25	<.0001
None, literacy	-0.530641804	-11.45	<.0001
Elementary school	-0.336089773	-9.25	<.0001
Middle school	-0.289918119	-8.26	<.0001
High school	-0.155157578	-4.77	<.0001
College	-0.003517787	-0.11	0.9087

Table 4.4 (Continued)

Variables	Coefficient	t-values	P-value
Head of household (continued)			
Marital status (divorced/separated)			
Single	-0.380305701	-8.73	<.0001
Married	0.144820990	3.72	0.0002
Widowed	0.062736872	1.46	0.1455
Health status (very bad)			
Very good	0.232838778	5.94	<.0001
Good	0.221623746	6.57	<.0001
Moderate	0.166981591	4.93	<.0001
Bad	0.164917703	4.77	<.0001
Household			
No. of household members (> 7)			
1	0.630706412	13.39	<.0001
2	0.262760996	6.99	<.0001
3	0.196783709	5.44	<.0001
4	0.220564347	6.25	<.0001
5	0.143346208	3.89	0.0001
6	0.054170429	1.30	0.1921
Proportion of dependents	-0.478707976	-15.44	<.0001
Community			
Proportion of skilled agricultural, forestry, & fishery workers	-0.106207708	-3.20	0.0014
Proportion of elementary workers	-0.095857791	-0.90	0.3672
Average per capita income	0.008575164	33.60	0.0001
Constant	3.069511343	27.04	<.0001
R^2 = 0.507876			
F = 297.94			<.0001

NOTE: Per capita income=household total income/number of adults in each household.

unemployed subjects. Service and sales workers were 0.713 times were less likely to do extra exercise than the unemployed. Skilled agricultural, forestry, and fishery workers 0.354 times, craft and related trades workers 0.631 times, and those in elementary occupations 0.578 times were less likely (Table 4.5).

The relative odds of doing physical exercise for people who were never educated and illiterate, never educated and literate, and graduated from elementary school were 0.161, 0.159, and 0.388 respectively (Table 4.6). Unmarried people were 1.720 times more likely to do extra exercise than divorced or separated ones. Having circulatory, respiratory, or bone diseases did not change the probability of performing exercise.

Among household variables, living in urban areas increased the probability of doing exercise 1.345 times over living in rural areas. If a community had more skilled agricultural, forestry, and fishery workers, people living there were less likely to do exercise. If people in a community were more likely to receive a health examination, people living there were more likely to exercise. The more people a community had who got education after a health examination, the fewer people in that community were likely to exercise.

Table 4.5 Prediction of probability of doing physical exercise (n=10430)

Variables	Coefficient	X^2	P-value
Predicted income			
Log per capita household income	0.4559	0.5182	0.4716
Log per capita household income^2	0.000733	0.0001	0.9929
Physical activity facility access (yes)			
No sports complex	0.0237	0.8688	0.3513
No swimming pool	-0.0492	1.1738	0.2786
No exercise hall	0.1419	0.3373	0.5614
No tennis courts	0.0201	0.6209	0.4307
No golf indoor center	0.0121	0.0206	0.8859
No physical training center	-0.2391	3.9294	0.0474
No aerobics	0.00422	0.0059	0.9387
Prices of physical exercise (Korean won)			
Aerobics, monthly lesson fee	-0.00001	10.1103	0.0015
Golf, monthly entrance fee	-1.78E-6	7.0521	0.0079
Swimming, per entrance	-0.00001	0.0947	0.7583
Individual			
Male /Female	0.3649	155.7785	<.0001
Age	0.0624	24.2139	<.0001
Age^2	-0.00062	21.1286	<.0001
Occupations (Unemployed)			
Legislators, senior officials, & managers	0.5692	4.0279	0.0448
Professionals	0.2791	5.0799	0.0242
Technicians & associate professionals	-0.0563	0.1956	0.6583
Clerks	-0.0150	0.0261	0.8716
Service & sales workers	-0.2036	5.7717	0.0163
Skilled agricultural, forestry, & fishery workers	-0.9046	39.7962	<.0001
Craft & related trade workers	-0.3260	10.8105	0.0010
Plant, machine operators, & assemblers	-0.0799	0.4448	0.5048
Elementary occupations	-0.4143	11.8793	0.0006
Armed forces	1.0169	4.1906	0.0406
Education (Graduate school)			
None, illiteracy	-1.0143	24.2479	<.0001
None, literacy	-1.0256	32.1569	<.0001
Elementary school	-0.1329	2.6399	0.1042
Middle school	0.3050	14.8017	0.0001
High school	0.5196	56.7180	<.0001

Table 4.5 (Continued)

Variables	Coefficient	X^2	P-value
Individual (continued)			
Education (continued)			
College	0.5355	45.4723	<.0001
Marital status (Divorced/separated)			
Single	0.5073	27.6182	<.0001
Married	-0.1982	8.3887	0.0038
Widowed	-0.2741	5.9342	0.0148
Diseases (Yes)			
Circulatory diseases	-0.0206	0.2147	0.6431
Respiratory diseases	0.0515	0.4267	0.5136
Bone diseases	-0.00030	0.0001	0.9918
Household			
No. of household members (> 7)			
1	-0.0590	0.2362	0.6269
2	0.0128	0.0386	0.8442
3	0.0769	1.9788	0.1595
4	0.0139	0.0746	0.7847
5	0.000664	0.0001	0.9917
6	0.0184	0.0351	0.8514
Proportion of dependents	0.1704	1.4173	0.2338
Residential location (rural)			
Urban	0.1491	11.9555	0.0005
Suburban	-0.00171	0.0018	0.9658
Community			
Proportion of skilled agricultural, forestry, & fishery workers	-0.5443	8.5513	0.0035
Proportion of elementary workers	0.2011	0.1724	0.6780
Average per capita income	-0.00032	0.0277	0.8677
Proportion receiving health examinations	0.8622	13.0720	0.0003
Proportion of receiving education after health examination	-0.4758	4.4379	0.0351
Constant	-3.6895	7.7741	0.0053

Note: Hosmer and Lemeshow Goodness-of-Fit Test: χ_8^2=12.2339, *P*=0.1411

Table 4.6 Physical exercise prediction: odds ratio (OR) and confidence interval (CI) of categorical explanatory variables (n=10430)

Variables	OR (CI)
Physical activity facility access (yes)	
Sports complex	1.049 (0.949-1.159)
Swimming pool	0.906 (0.759-1.083)
Exercise hall	1.328 (0.510-3.462)
Tennis courts	1.041 (0.942-1.151)
Golf	1.025 (0.735-1.428)
Physical training center	0.620 (0.386-0.995) *
Aerobics	1.008 (0.814-1.250)
Individual	
Male /Female	2.075 (1.850-2.327)*
Occupations (Unemployed)	
Legislators, senior officials, & managers	1.544 (0.839-2.842)*
Professionals	1.156 (0.897-1.489)*
Technicians & associate professionals	0.826 (0.635-1.075)
Clerks	0.861 (0.719-1.032)
Service & sales workers	0.713 (0.607-0.838)*
Skilled agricultural, forestry, & fishery workers	0.354 (0.263-0.476)*
Craft & related trade workers	0.631 (0.515-0.773)*
Plant, machine operators, & assemblers	0.807 (0.628-1.037)
Elementary occupations	0.578 (0.452-0.738)*
Armed forces	2.417 (0.827-7.060)*
Education (Graduate school)	
None, illiteracy	0.161 (0.089-0.289)*
None, literacy	0.159 (0.093-0.273)*
Elementary school	0.388 (0.266-0.567)*
Middle school	0.602 (0.419-0.864)
High school	0.746 (0.535-1.041)*
College	0.758 (0.551-1.042)*
Marital status (Divorced/separated)	
Single	1.720 (1.148-2.576)*
Married	0.849 (0.588-1.227)*
Widowed	0.787 (0.509-1.217)*

Table 4.6 (Continued)

Variables	**OR (CI)**
Individual (continued)	
Diseases (Yes)	
Circulatory diseases	0.960 (0.806-1.142)
Respiratory diseases	1.108 (0.814-1.510)
Bone diseases	0.999 (0.890-1.122)
Household	
No. of household members (> 7)	
1	1.005 (0.664-1.521)
2	1.079 (0.774-1.505)
3	1.151 (0.833-1.590)
4	1.081 (0.785-1.488)
5	1.066 (0.766-1.484)
6	1.086 (0.750-1.572)
Residential location (rural=1)	
Urban	1.345 (1.146-1.579)*
Suburban	1.157 (0.995-1.345)

OR estimate statistically significant at *$p<0.05$

4.2.3. Dietary intake prediction

4.2.3.1. Daily caloric intake

This model explained 20.31% of the variability. The daily dietary intake was predicted by Model (5) as shown in the previous chapter. As seen in Table 4.7, the predicted income did not have any influence on an individual dietary intake. Among food prices, the prices of chicken, Soju (Korean traditional liquor), and soybean oil had statistically significant effects on daily dietary intake. As prices of soybean oil and Soju decreased, energy consumption increased. On the other hand, as the chicken price increased, more calories were consumed.

People's daily caloric intake was supposed to be positively correlated with their basal metabolic rate. Subjects without diabetes or cancer consumed 57.04 kcal and 160.97 kcal more energy than those having these disesases. Most of the occupation groups, except for legislators, senior officials, and managers and members of armed forces, had more caloric intake than the unemployed, with a range of 65.33 kcal to 201.96kcal. Less educated individuals from the never educated to middle school graduated categories ate less than the more educated. Marital status did not influence people's daily energy intake.

As the proportion of dependents in a household increased, its members consumed more energy. Neither the residential location nor the number of household members affected individual dietary intake. No community variables were statistically significant.

Table 4.7 Prediction of daily energy intake (n=10430)

Variables	Coefficient	t-values	P-value
Predicted income			
Log per capita household income	89.1127259	0.63	0.5304
Log per capita household income^2	3.8610417	0.20	0.8391
Food commodity price			
Rice	-2.188363922	-0.89	0.3713
Wheat	-3.693547427	-0.36	0.7174
Instant noodles	1.382726328	0.66	0.5101
Beef, imported	-0.137829686	-1.21	0.2258
Poultry	1.259526227	2.31	0.0212
Eggs	-0.995384700	-1.32	0.1875
Delivered milk	-0.130435331	-0.22	0.8245
Bean curd	-0.09324107	-0.05	0.9639
Apples	-0.031536994	-0.36	0.7160
Orange juice	-0.198262041	-0.87	0.3819
Pizza	-0.004527408	-0.18	0.8584
Coke	0.361227283	0.41	0.6795
Soda	-0.462492077	-0.54	0.5878
Soju	-1.427002450	-2.86	0.0042
Sugar	5.653029650	0.74	0.4600
Soybean oil	-5.845507956	-2.30	0.0213
Individual			
Food insecurity (Skipping meals due to lack of financial resources)	167.5059843	1.19	0.2331
Basal metabolic rate**f(weight, gender, age)	0.9085600	30.85	<.0001
Occupations (Unemployed)			
Legislators, senior officials, & managers	65.3372108	0.76	0.4475
Professionals	91.5932249	2.53	0.0115
Technicians & associate professionals	162.0211148	4.32	<.0001
Clerks	78.2980811	3.15	0.0017
Service & sales workers	94.7946897	4.64	<.0001
Skilled agricultural, forestry, & fishery workers	201.9580579	7.45	<.0001
Craft & related trade workers	184.1559423	7.09	<.0001
Plant, machine operators, & assemblers	155.8467919	4.59	<.0001
Elementary occupations	175.9133259	6.29	<.0001
Armed forces	-90.2849035	-0.62	0.5328

Table 4.7 (Continued)

Variables	Coefficient	t-values	P-value
Education (Graduate school)			
None, literacy	-276.5891490	-4.57	<.0001
None, illiteracy	-226.7543862	-3.87	0.0001
Elementary school	-179.9982188	-3.44	0.0006
Middle school	-135.2433862	-2.63	0.0085
High school	-53.6654809	-1.11	0.2652
College	-41.5114992	-0.90	0.3689
Marital status (divorced/separated)			
Single	-29.4594339	-0.60	0.5518
Married	31.4404021	0.67	0.5010
Widowed	-22.5190782	-0.44	0.6564
Diseases (Yes)			
Diabetes	57.0412955	1.86	0.0636
Cancer	160.9671395	2.04	0.0418
Gastrointestinal diseases	36.4250083	1.91	0.0568
Household			
Proportion of dependents	86.0651215	2.51	0.0121
Residential location (rural)			
Urban	-5.1788664	-0.23	0.8164
Suburban	-25.1134334	- 1.33	0.1828
No. of household members (> 7)			
1	59.5651583	1.22	0.2240
2	56.9895397	1.38	0.1673
3	75.2067746	1.85	0.0647
4	45.2017990	1.12	0.2624
5	20.3750615	0.49	0.6266
6	4.7175276	0.10	0.9198
Community			
Proportion of skilled agricultural, forestry, & fishery workers	18.7494038	0.48	0.6317
Proportion of elementary workers	91.7454197	0.73	0.4635
Average per capita income	-0.2406818	-0.51	0.6102
Proportion of receiving health examination	22.8538175	0.32	0.7504
Proportion of receiving education after health examination	-79.1215863	-0.91	0.3635
Constant	190.3409259	0.41	0.6783
R^2=0.203122			
F =47.22			<.0001

4.2.3.2. Daily fat intake

The explanatory power of the model was 16.93%. The daily fat intake was predicted by Model (6) in the previous chapter. As shown in Table 4.8, the predicted income did not have any effects on an individual's fat intake. As prices of bread, instant noodles, Soju (Korean traditional liquor), and soybean oil increased, the daily fat consumption decreased.

Among individual characteristics, basal metabolic rate was positively related to fat intake. Daily fat intake did not differ between subjects with and without diseases. Technicians, associate professionals, service and sales workers, craft and related trade workers, and people in elementary occupations consumed more fat than the unemployed. Less educated groups from the never educated to middle school graduated categories had less fat intake than the more educated. Singles consumed more fat than the reference group. Residential locations of a household did not affect individual fat intake. No community variables were statistically significant for fat intake prediction.

4.2.4. Prediction of waist hip ratio (WHR)

4.2.4.1. Predicted with caloric intake

This prediction was based on Model (1). As shown in Table 4.9, the R^2 of this model was 0.447011. The predicted per capita household income did not influence the individual WHR. The linear term of daily energy intake was positively related to the WHR, whereas its squared term was negatively related. That is, a WHR increased as energy intake increased up to 4220.38 kcal (getting the maximum value from 2x-0.000000372 kcal +0.0003129962 which was taken from first derivatives of -0.0000000372 $kcal^2$+0.0003129962

Table 4.8 Prediction of fat intake (n=10430)

Variables	Coefficient	t-values	P-value
Predicted income			
Log per capita household income	-1.66941458	-0.28	0.7789
Log per capita household income^2	1.15015114	1.45	0.1483
Food commodity price			
Bread	-0.028617367	-2.58	0.0099
Wheat	0.5279558548	1.24	0.2134
Instant noodles	-0.285005199	-3.34	0.0008
Beef, imported	0.00261227	0.66	0.5117
Pork	0.00125936	0.08	0.9398
Poultry	0.03487504	1.44	0.1493
Delivered milk	0.00570008	0.23	0.8161
Bean curd	-0.016559827	-1.91	0.0563
Apples	-0.00144235	-0.39	0.6933
Orange juice	0.00384659	0.41	0.6807
Bananas	0.118622665	0.90	0.3692
Citrus fruits	0.0074503206	1.18	0.2387
Pizza	-0.00019739	-0.18	0.8534
Coke	0.02558679	0.65	0.5128
Soda	-0.03166504	-0.90	0.3661
Soju	-0.03870864	-1.85	0.0642
Soybean oil	-0.233902769	-2.64	0.0083
Individual			
Food insecurity (Skipping meals due to lack of financial resources)	0.19606966	0.03	0.9734
Basal metabolic rate *f(weight, gender, age)	0.02142042	17.40	<.0001
Occupations (Unemployed)			
Legislators, senior officials, & managers	-1.57592521	-0.44	0.6611
Professionals	1.76091974	1.16	0.2450
Technicians & associate professionals	5.92300732	3.78	0.0002
Clerks	1.66830119	1.60	0.1086
Service & sales workers	2.39074228	2.80	0.0051
Skilled agricultural, forestry, & fishery workers	1.99491051	1.76	0.0782
Craft & related trade workers	3.82363479	3.52	0.0004
Plant, machine operators, & assemblers	2.61148825	1.84	0.0654
Elementary occupations	2.97309578	2.54	0.0110
Armed forces	-8.48434976	-1.40	0.1607

Table 4.8 (Continued)

Variables	**Coefficient**	**t-values**	**P-value**
Education (Graduate school)			
None, literacy	-14.37599144	-5.69	<.0001
None, illiteracy	-13.77304006	-5.63	<.0001
Elementary school	-11.20881723	-5.13	<.0001
Middle school	-7.94758964	-3.70	0.0002
High school	-3.65325072	-1.82	0.0693
College	-1.34349345	-0.70	0.4862
Marital status (divorced/separated)			
Single	5.10407955	2.47	0.0136
Married	0.30820092	0.16	0.8746
Widowed	-0.06132541	-0.03	0.9769
Diseases (Yes)			
Diabetes	1.44884548	1.13	0.2593
Cancer	4.43888227	1.34	0.1791
Gastrointestinal diseases	0.23823258	0.30	0.7655
Household			
Proportion of dependents	2.37695093	1.66	0.0974
Residential location (rural)			
Urban	1.80735403	1.85	0.0649
Suburban	0.77953253	0.99	0.3239
No. of household members (> 7)			
1	-2.25594659	-1.10	0.2710
2	-0.69344702	-0.40	0.6879
3	-0.13808243	-0.08	0.9354
4	-1.02374519	-0.61	0.5442
5	-1.65182785	-0.94	0.3457
6	-3.94333286	-2.01	0.0443
Community			
Proportion of skilled agricultural, forestry, & fishery workers	0.66051442	0.40	0.6873
Proportion of elementary workers	5.05503749	0.97	0.3316
Average per capita income	-0.01352368	-0.69	0.4922
Proportion receiving health examination	-0.60841716	-0.20	0.8396
Proportion of receiving education after health examination	-5.77284473	-1.61	0.1082
Constant	7.24593433	0.37	0.7078
R^2=0.169347			
F =37.10			<.0001

kcal). As expected, the WHR decreased as the probability of doing physical exercise increased.

The WHR was higher for males than females. Age and age squared were positively and negatively related to WHR, respectively. Since the maximum value was 138 years, WHR increased as the age increased in this sample. The WHR was higher than the reference group in most occupational groups, except for legislators, senior officials, and managers. Members of the armed forces had a higher WHR than the unemployed. Marital status was not significantly related to central adiposity reflected as WHR. People with either diabetes or circulatory diseases had higher WHR than people without these diseases.

Urban and rural residents had a lower WHR than rural residents. As the proportion of skilled agricultural, forestry, and fishery workers living in a community increased, the WHR of people living in the community decreased. As the average per capita income of the community increased, the WHR of subjects living in the community decreased. The more people in the community received health examinations, the lower the WHR of people.

4.2.4.2. Predicted with fat intake

Based on Model (2) in the previous chapter, this model explained 42.74% of the variability (Table 4.10). Predicted income had only a marginal effect on WHR in the linear term (p=0.0591) but a statistically significant effect in the squared term. The linear term of the predicted fat intake was positively related to the WHR. The predicted probability of doing physical exercise did not influence the WHR.

WHR was higher for males than females. The linear and squared terms of age were positively and negatively related to WHR, respectively. Since the maximum value was 96 years, WHR increased as age increased in the sample. Subjects working as legislators, senior officials, and managers and members of the armed forces had higher WHR than the unemployed. Others had lower WHR than the reference group. Singles had lower WHR than the reference group. People with diabetes or circulatory diseases had higher WHR than people without those diseases.

Urban and suburban residents had lower WHR than rural residents. If a community had a higher proportion of skilled agricultural, forestry, and fishery or elementary workers, people living in the community had lower WHR. As the average per capita income of the community increased, the WHR of people living in the community decreased. The more people in a community received health examinations, the lower the WHR of people in the community. As the proportion of people who were educated after health examinations increased in a community, the WHR of people living in the community increased.

4.3. Relative importance of income, price, community characteristics, dietary intake, and physical exercise

In the previous analyses, the income, prices, community characteristics, dietary intake, and probability of doing physical exercise influenced the WHR. In this part, the relative importance of those predictors is investigated.

Table 4.9 Prediction of waist-hip-ratio with caloric intake (n=10430)

Variables	Coefficient	t-values	P-value
Predicted income			
Log per capita household income	-.0001773408	-0.01	0.9895
Log per capita household income^2	-.0021046565	-1.18	0.2392
Predicted caloric intake			
Caloric intake	0.0003129962	12.58	<.0001
Calorie intake^2	-.0000000372	-6.43	<.0001
Predicted physical exercise			
Probability of doing physical exercise	-.0360921110	-2.47	0.0136
Individual			
Male (Female)	0.0170722392	6.44	<.0001
Age	0.0033821602	10.21	<.0001
Age^2	-.0000121853	-3.64	0.0003
Occupations (unemployed)			
Legislators, senior officials, & managers	0.0125292403	1.49	0.1364
Professionals	-.0113595909	-3.24	0.0012
Technicians & associate professionals	-.0296680053	-8.18	<.0001
Clerks	-.0089170076	-3.74	0.0002
Service & sales workers	-.0124176999	-5.77	<.0001
Skilled agricultural, forestry, & fishery workers	-.0365350623	-10.47	<.0001
Craft & related trade workers	-.0240689295	-8.24	<.0001
Plant, machine operators, & assemblers	-.0243824390	-7.25	<.0001
Elementary occupations	-.0300000464	-10.12	<.0001
Armed forces	0.0405805196	2.87	0.0041
Education (Graduate school)			
None, illiteracy	0.0529889195	7.64	<.0001
None, literacy	0.0461881066	6.70	<.0001
Elementary school	0.0355808845	6.06	<.0001
Middle school	0.0221968689	4.19	<.0001
High school	0.0054733673	1.15	0.2497
College	0.0020667262	0.46	0.6479
Marital status (Divorced / separated)			
Single	-.0013655321	-0.26	0.7926
Married	-.0070197050	-1.61	0.1068
Widowed	0.0009662329	0.20	0.8433

Table 4.9 (Continued)

Variables	Coefficient	t-values	P-value
Diseases (Yes)			
Diabetes	-.0384057234	-13.00	<.0001
Cancer	-.0075095776	-0.99	0.3222
Gastrointestinal diseases	-.0030039818	-1.59	0.1126
Respiratory diseases	-.0018075758	-0.53	0.5981
Circulatory diseases	-.0110529314	-5.70	<.0001
Bone disease	-.0015313933	-1.08	0.2803
Household			
Residential location (rural)			
Urban	-.0042807947	-2.48	0.0131
Suburban	-.0042002337	-2.34	0.0195
Community			
Proportion of skilled agricultural, forestry, & fishery workers	-.0087332234	-2.28	0.0226
Proportion of elementary workers	-.0076512041	-0.66	0.5090
Average per capita income	-.0000830106	-1.98	0.0482
Proportion receiving health examinations	-.0178619763	-2.74	0.0062
Proportion of receiving education after health examinations	0.0069287125	1.22	0.2240
Constant	0.3789587077	11.02	<.0001
R^2=0.447011			
F =209.95			<.0001

Table 4.10 Prediction of waist-hip-ratio with fat intake (n=10430)

Variables	Coefficient	t-values	P-value
Predicted income			
Log per capita household income	0.0270570852	1.89	0.0591
Log per capita household income^2	-.0081962795	-4.33	<.0001
Predicted fat intake			
Fat intake	0.0057614922	12.15	<.0001
Fat intake^2	-.0000032179	-0.57	0.5670
Predicted physical exercise			
Probability of doing physical exercise	-.0279877258	-1.84	0.0664
Individual			
Male (Female)	0.0229169327	8.49	<.0001
Age	0.0041192006	12.02	<.0001
Age^2	-.0000213800	-6.20	<.0001
Occupations (unemployed)			
Legislators, senior officials, & managers	0.0277618079	3.24	0.0012
Professionals	-.0076859153	-2.16	0.0311
Technicians & associate professionals	-.0380968790	-10.08	<.0001
Clerks	-.0067339318	-2.78	0.0055
Service & sales workers	-.0094351886	-4.31	<.0001
Skilled agricultural, forestry, & fishery workers	-.0132309840	-3.82	0.0001
Craft & related trade workers	-.0165987129	-5.61	<.0001
Plant, machine operators, & assemblers	-.0143628068	-4.24	<.0001
Elementary occupations	-.0175849024	-5.94	<.0001
Armed forces	0.0733336844	5.06	<.0001
Education (Graduate school)			
None, illiteracy	0.0868109761	11.52	<.0001
None, literacy	0.0861256089	11.50	<.0001
Elementary school	0.0694708680	11.18	<.0001
Middle school	0.0459097122	8.36	<.0001
High school	0.0176438489	3.63	0.0003
College	0.0035680698	0.78	0.4382
Marital status (Divorced / separated)			
Single	-.0353718580	-6.67	<.0001
Married	-.0068332076	-1.54	0.1229
Widowed	-.0029069169	-0.58	0.5589

Table 4.10 (Continued)

Variables	**Coefficient**	**t-values**	**P-value**
Diseases (Yes)			
Diabetes	-.0366976797	-12.22	<.0001
Cancer	-.0033313283	-0.43	0.6663
Gastrointestinal diseases	0.0025185228	1.32	0.1878
Respiratory diseases	-.0004884722	-0.14	0.8887
Circulatory diseases	-.0127672312	-6.48	<.0001
Bone disease	-.0024416137	-1.69	0.0906
Household			
Residential location (rural)			
Urban	-.0168789946	-9.56	<.0001
Suburban	-.0141631285	-7.72	<.0001
Community			
Proportion of skilled agricultural, forestry, & fishery workers	-.0088154540	-2.26	0.0240
Proportion of elementary workers	-.0394156568	-3.33	0.0009
Average per capita income	-.0001000908	-2.34	0.0193
Proportion receiving health examinations	-.0163044586	-2.43	0.0152
Proportion receiving education after health examination	0.0343836872	5.88	<.0001
Constant	0.5930762547	20.71	<.0001
R^2=0.427460			
F =193.91			<.0001

4.3.1. Income

Predicted income was not related to the daily energy and fat intakes (Tables 4.7 and 4.8). Neither did it influence the WHR in the prediction of WHR with energy intake (Table 4.9). Its squared term only had an effect in prediction with fat intake (Table 4.10). To investigate a direct effect of income on WHR, three analyses were conducted: 1) with income, without dietary intake, and with physical exercise (Model [7] in the previous chapter); 2) without income, with energy intake, and with physical exercise (Model [8]); and 3) without income, with fat intake, and with physical exercise (Model [9]). The R^2 for these analyses were 0.3510, 0.4447, and 0.4175, respectively, and the second model had the best explanatory power. Without the variables of dietary intake, the income and income square became statistically significant. Based on coefficients, the maximum value from the first derivatives was $e^{3.6821}$, which was 397,297 *won* (around U.S.$400). That means the WHR increased as the income increased up to 397, 297 *won*; after that, it decreased as the income increased.

The probability of doing physical exercise was not related to the WHR in the first analysis. In the second analysis, coefficients and t-values of the caloric intake and its squared term had similar effects, as shown in the analysis with both income and caloric intake in Table 4.9. The probability of doing physical exercise, on the other hand, had an increased effect on the WHR in both coefficients from -0.0361 to -0.0707 and t-values from -2.47 to -5.19. This showed that income effects were mediated more through physical exercise than dietary energy intake. Similar results were shown in analyses with fat intake. In the third analysis, coefficients and t-values of fat intake and its squared term were similar to those in the analysis with both income and fat intake in Table 4.10. Meanwhile, the effect of doing physical exercise increased in both coefficients from -0.0280 to -0.0994 and t-values from -1.84 to -6.91. This also indicated that income effects were more mediated through physical exercise than fat intake.

Among individual characteristics, age, gender, and occupation had similar effects in all analyses. Only in the first prediction craft and related trade workers have a higher WHR than the reference group; the second and third analyses showed the opposite. The effect of education was similar in all analyses but more clearly shown in the third model. Singles had a smaller WHR than the reference group in the first and third analyses. People with diabetes, circulatory diseases, or bone diseases had a higher WHR than people without those diseases in all analyses. People with cancer or gastrointestinal diseases had a smaller WHR than people without those diseases in the first analysis. Urban and suburban residents had a smaller WHR than rural residents in all analyses.

Regarding community characteristics, in the first analysis, as the proportion of people receiving health examinations increased, the WHR decreased. As the proportion of people educated after health examination in a community increased, the WHR of people living in the community increased. In the second and third analyses, as the proportion of skilled agricultural, forestry, and fishery workers and the average per capita income increased, the WHR decreased. The proportion of elementary occupations was negatively related to subjects' WHR only in the third analysis.

Table 4.11 Comparison of prediction with and without income and energy intake (N=10430)

Variables	1) With income		2) Without income With energy		3) Without income With fat	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Predicted log per capita household income	0.0447058	3.10*				
Predicted log per capita household income^2	-.0060706	-3.15*				
Predicted energy and fat intake			0.0002928	11.93*	0.0043127	9.95*
Predicted energy and fat intake^2			-.0000000	-5.79*	0.0000068	1.29
Predicted probability of doing physical exercise	0.0224675	1.43	-.0706510	-5.19*	-.0994015	-6.91*
Individual						
Male (Female)	0.0511554	18.68*	0.0237337	9.68*	0.0387118	15.82*
Age	0.0046152	13.18*	0.0038862	12.15*	0.0053259	15.98*
Age^2	-.0000351	- 10.06*	-.0000162	-4.96*	-.0000322	-9.52*
Education (Graduate school)						
None, illiteracy	0.0177033	2.39*	0.0485548	7.02*	0.0678346	9.12*
None, literacy	0.0188663	2.55*	0.0412442	6.01*	0.0660348	8.96*
Elementary school	0.0144989	2.29*	0.0320040	5.47*	0.0560209	9.14*
Middle school	0.0053805	0.94	0.0204941	3.88*	0.0392897	7.18*
High school	-.0037717	-0.73	0.0046177	0.98	0.0151841	3.11*
College	-.0052798	-1.08	0.0001233	0.03	-.0001940	-0.04
Marital status (Divorced / separated)						
Single	-.0189110	-3.38*	0.0068087	1.35	-.0151383	-2.95*
Married	-.0033112	-0.70	-.0081560	-1.87	-.0087558	-1.96*
Widowed	0.0026869	0.51	-.0017349	-0.36	-.0068988	-1.38

Table 4.11 (Continued)

Variables	1) With income		2) Without income With energy		3) Without income With fat	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Individual (continued)						
Occupations (unemployed)						
Legislators, senior officials, & managers	0.0200565	2.20*	0.0124115	1.47	0.0266336	3.08*
Professionals	-.0058585	-1.55	-.0136003	-3.93*	-.0128845	-3.63*
Technicians & associate professionals	-.0073184	-1.89	-.0325971	-9.06*	-.0423079	-11.14*
Clerks	0.0006375	0.25	-.0116738	-4.98*	-.0121096	-5.02*
Service & sales workers	0.0044479	1.94	-.0159052	-7.62*	-.0156920	-7.27*
Skilled agricultural, forestry, & fishery workers	-.0087275	-2.37*	-.0414245	-12.21*	-.0249142	-7.37*
Craft & related trade workers	0.0061715	2.02*	-.0288277	-10.19*	-.0250537	-8.60*
Plant, machine operators, & assemblers	-.0006632	-0.18	-.0271231	-8.12*	-.0190371	-5.60*
Elementary occupations	-.0043407	-1.39	-.0322374	-10.96*	-.0221573	-7.47*
Armed forces	0.0180328	1.18	0.0475607	3.37*	0.0832852	5.71*
Diseases (yes)						
Diabetes	-.0320600	-10.04*	-.0384349	-12.99*	-.0365993	-12.09*
Cancer	0.0265366	3.26*	-.0066701	-0.88	0.0012131	0.16
Gastrointestinal diseases	0.0081226	4.00*	-.0027831	-1.47	0.0030703	1.59
Respiratory diseases	-.0005432	-0.15	-.0013714	-0.40	0.0006383	0.18
Circulatory diseases	-.0187373	-8.97*	-.0115719	-5.96*	-.0142814	-7.20*
Bone disease	-.0053368	-3.48*	-.0018799	-1.32	-.0031499	-2.17*
Household						
Residential location (rural)						
Urban residents	-.0128277	-6.91*	-.0035748	-2.09*	-.0136858	-7.77*
Suburban residents	-.0113884	5.87*	-.0034997	-1.96	-.0113947	-6.20*

Table 4.11 (Continued)

Variables	1) With income		2) Without income With energy		3) Without income With fat	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Community						
Proportion of skilled agricultural, forestry, & fishery workers	-.0020741	-0.50	-.0099957	-2.65*	-.0127360	-3.28*
Proportion of elementary workers	-.0108730	-0.87	-.0058720	-0.51	-.0309810	-2.60*
Average per capita income	-.0000758	-1.67	-.0002416	-7.44*	-.0004296	-12.50*
Proportion receiving health examinations	-.0361086	-5.12*	-.0105903	-1.64	-.0023850	-0.36
Proportion receving education after health examination	0.0226207	3.67*	0.0004517	0.08	0.0177554	3.08*
Constant	0.66874841	22.17*	0.3739395	13.89*	0.6152389	40.70*
R^2 **F**	**R^2**=0.351 F=147.86*		**R^2**=0.445 F=219.00*		**R^2**=0.418 **F** =196.01*	

***Statistically significant at *P*<0.05**

4.3.2. Price

In both predictions of energy and fat intake, prices of Soju (Korean traditional liquor) and soybean oil were negatively related to the daily energy and fat intake. In the full model, the assumption was that food prices would only influence body measures through dietary intake. To investigate whether this would be true, a direct effect of food commodity prices on the WHR was tested in this section. The prediction was tested without dietary intake variables (Model [10] in the previous chapter). Some selected food commodity prices related to the food trade liberalization were included, but *Soju* (Korean traditional liquor) was of particular interest due to its statistically significant effect in the previous analyses.

As shown in Table 4.12, the model explained 45.17% of the variability, which was similar to that for WHR in the prediction with the caloric intake prediction (44.70%). Prices had direct effects on the WHR: as prices of corn oil, pizza, and hamburger increased, the individual WHR decreased as expected. However, in opposition to expectation, the chicken price was positively related to the WHR. It might be that an increase in chicken prices discourages chicken consumption and subsequent substitution is directed toward more calorie-dense commodities, increasing the individual energy intake. The elevated caloric intake then increases the central adiposity. The predicted income was not significant. The predicted probability of doing physical exercise was negatively related to the WHR.

The WHR for males was higher than for females. Age and age squared were positively and negatively related to WHR, respectively. Among occupational groups, only technicians and associate professionals had a smaller WHR than the reference group. Education and marital status did not

Table 4.12 Prediction of waist-hip-ratio with selected prices (n=10430)

Variables	Coefficient	t-values	P-value
Predicted income			
Log per capita household income	-.0001773408	-0.01	0.9895
Log per capita household income^2	-.0021046565	-1.18	0.2392
Predicted physical exercise			
Probability of doing physical exercise	-.0307304876	-1.96	0.0496
Food commodity prices			
Rice	-0.000175068	-0.74	0.4580
Imported beef	0.000006506	0.61	0.5422
Orange juice	0.000016115	0.74	0.4603
Imported bananas	-0.000344179	-1.27	0.2033
Pork	0.000068773	1.91	0.0565
Poultry	0.000136337	2.70	0.0069
Soybean oil	0.000629587	1.51	0.1316
Corn oil	-0.000353269	-2.00	0.0455
Soda	0.000116829	1.85	0.0648
Soju	-0.000068809	-1.46	0.1443
Pizza	-0.000007647	-3.19	0.0014
Hamburgers	-0.000186682	-2.35	0.0190
Sugar	-0.000352814	-0.54	0.5869
Individual			
Basal metabolic rates	0.0001495491	43.10	<.0001
Male **(Female)**	0.0154455916	5.60	<.0001
Age	0.0036262748	11.06	<.0001
Age^2	-.0000149421	-4.55	<.0001

Table 4.12 (Continued)

Variables	Coefficient	t-values	P-value
Individual (continued)			
Occupations (unemployed)			
Legislators, senior officials, & managers	0.0163865317	1.94	0.0521
Professionals	0.0000185915	0.01	0.9958
Technicians & associate professionals	-.0073896493	-2.07	0.0388
Clerks	0.0000366292	0.02	0.9876
Service & sales workers	0.0002114846	0.10	0.9212
Skilled agricultural, forestry, & fishery workers	-.0033620892	-0.96	0.3382
Craft & related trade workers	0.0019321767	0.68	0.4979
Plant, machine operators, & assemblers	-.0024348070	-0.74	0.4612
Elementary occupations	-.0037832207	-1.29	0.1974
Armed forces	0.0251551138	1.78	0.0746
Education (Graduate school)			
None, illiteracy	0.0054288659	0.78	0.4334
None, literacy	0.0076814777	1.10	0.2700
Elementary school	0.0085173442	1.44	0.1510
Middle school	0.0038693133	0.73	0.4662
High school	0.0002094867	0.04	0.9647
College	-.0010083148	-0.22	0.8231
Marital status (Divorced / separated)			
Single	-.0088000928	-1.70	0.0894
Married	-.0025600030	-0.59	0.5557
Widowed	-.0047632296	-0.98	0.3278

Table 4.12 (Continued)

Variables	Coefficient	t-values	P-value
Individual (continued)			
Diseases (Yes)			
Diabetes	-.0286217228	-9.73	<.0001
Cancer	0.0211038410	2.81	0.0049
Gastrointestinal diseases	0.0029148678	1.56	0.1196
Respiratory diseases	-.0016668219	-0.49	0.6265
Circulatory diseases	-.0110224557	-5.71	<.0001
Bone disease	-.0015401664	-1.09	0.2777
Household			
Residential location (rural)			
Urban	-.0069622956	-3.27	0.0011
Suburban	-.0083567262	-4.53	<.0001
Community			
% skilled agricultural, forestry, & fishery workers	-.0088096235	-2.23	0.0257
% Elementary workers	-.0064310092	-0.55	0.5851
Average per capita income	-.0000914231	-2.15	0.0312
% Receiving health examinations	-.0163228367	-2.26	0.0241
% Receiving education after health examinations	0.0007308879	0.09	0.9300
Constant	0.5765656265	12.86	<.0001
R^2=0.451710			
F=164.41			<.0001

Table 4.13 Prediction of waist-hip-ratio with key prices related to trade (n=10430)

Variables	Coefficient	t-values	P-value
Predicted income			
Log per capita household income	0.0208143784	1.57	0.1175
Log per capita household income^2	-.0027609249	-1.55	0.1201
Predicted physical exercise			
Probability of doing physical exercise	-.0314873738	-2.08	0.0379
Food commodity prices			
Imported beef	0.0007889387	1.01	0.3134
Soybean oil	-.0361939876	-2.67	0.0077
Soda	0.0086023314	1.63	0.1041
Pizza	-.0007312926	-3.38	0.0007
Hamburgers	-.0120252279	-1.70	0.0883
Individual			
Basal metabolic rates	0.0001495293	43.13	<.0001
Male **(Female)**	0.0155213050	5.73	<.0001
Age	0.0036215105	11.11	<.0001
Age^2	-.0000149256	-4.57	<.0001

Table 4.13 (Continued)

Variables	Coefficient	t-values	P-value
Individual (continued)			
Occupations (unemployed)			
Legislators, senior officials, & managers	0.0170163293	2.02	0.0431
Professionals	-.0001213194	-0.03	0.9723
Technicians & associate professionals	-.0075118727	-2.10	0.0356
Clerks	0.0000560703	0.02	0.9811
Service & sales workers	0.0001220717	0.06	0.9542
Skilled agricultural, forestry, & fishery workers	-.0033466235	-0.97	0.3331
Craft & related trade workers	0.0019026884	0.67	0.5020
Plant, machine operators, & assemblers	-.0023733155	-0.72	0.4725
Elementary occupations	-.0038938331	-1.34	0.1806
Armed forces	0.0257022550	1.82	0.0683
Education (Graduate school)			
None, illiteracy	0.0049331681	0.72	0.4734
None, literacy	0.0075220842	1.09	0.2763
Elementary school	0.0081366144	1.38	0.1674
Middle school	0.0034448747	0.65	0.5150
High school	-.0000980928	-0.02	0.9835
College	-.0011878999	-0.26	0.7921
Marital status (Divorced / separated)			
Single	-.0089332251	-1.73	0.0839
Married	-.0025935541	-0.60	0.5504
Widowed	-.0047701809	-0.98	0.3269

Table 4.13 (Continued)

Variables	**Coefficient**	**t-values**	**P-value**
Individual (continued)			
Diseases (Yes)			
Diabetes	-.0284191427	-9.66	<.0001
Cancer	0.0208669780	2.78	0.0054
Gastrointestinal diseases	0.0028055586	1.50	0.1341
Respiratory diseases	-.0018229938	-0.53	0.5944
Circulatory diseases	-.0110996504	-5.75	<.0001
Bone disease	-.0014592235	-1.03	0.3037
Household			
Residential location (rural)			
Urban	-.0076975850	-3.81	0.0001
Suburban	-.0086410675	-4.74	<.0001
Community			
% skilled agricultural, forestry, & fishery workers	-.0069056455	-1.79	0.0737
% Elementary workers	-.0063063892	-0.54	0.5896
Average per capita income	-.0000867286	-2.06	0.0391
% Receiving health examinations	-.0146378907	-2.04	0.0414
% Receiving education after health examinations	-.0026761449	-0.33	0.7394
Constant	0.5758856809	13.98	<.0001
R^2=0.450766 **F**=193.71			<.0001

have an effect on the WHR. The WHR was higher for subjects with diabetes or circulatory diseases than for those without these diseases, whereas it was smaller in subjects with cancer. Urban and suburban residents had a smaller WHR than rural residents. Among community variables, the proportion of skilled agricultural, forestry, and fishery workers, the average per capita income, and the proportion of people who received health examinations were negatively related to the WHR.

When the model was run with key price variables, it explained 45.08% of the variability (Table 4.13). Prices had direct effects on the WHR: as prices of soybean oil (p=0.0077), pizza (p=0.0007), and hamburger (p=0.08) increased, the individual WHR decreased as expected.

4.3.3. Comparison of effects between predictors

In this section, effects of the income, prices, physical exercise, energy and fat intake, and community characteristics were compared. Table 4.14 summarizes results for the previous prediction. First, in summary there were six models for the WHR prediction:

Model 1: the full model (with caloric intake)

Model 2: the full model (with fat intake)

Model 3: the reduced model without dietary intake

Model 4: the reduced model without income (with caloric intake)

Model 5: the reduced model without income (with fat intake)

Model 6: the reduced model: dietary intake was replaced by selected food prices

In the prediction of central adiposity as measured by the WHR, energy intake and its squared term (Models 1 and 4), and the linear term of fat intake (models 2 and 5) were significant whenever they were included. Interestingly, only prices, not income or community characteristics, had an influence on these two dietary variables. In addition, food prices related to trade liberalization were directly related to the WHR.

The probability of doing physical exercise was also significant whenever it was included except with Models 2 and 3. The higher the probability of doing exercise, the lower WHR. This probability of doing physical exercise was influenced by the prices of and access to health facilities, not by income. Among community characteristics, the more skilled agricultural, forestry, and fishery workers, the lower the probability of doing physical exercise, as expected. The more people in a community practiced preventive health care, as measured by receiving health examinations, the higher the probability of doing exercise, as expected.

Income and its squared term had significant effects on the WHR only in Models 2 and 3. They were not significant when energy intake or its replacement, food commodity prices related to trade, was included. They became significant without dietary intake variables (Model 3) or marginally significant with fat intake (Model 2). Interestingly, when income was significant, the probability of doing physical exercise became insignificant. In the study, physical exercise meant doing extra exercise up to the point of becoming out of breath more than seven minutes per week. There might be a possible relation between income and physical exercise in this sense. The average per capita income of a community was significant in all models except when income was significant (Model 3). Thus, it seemed that the average income level of a community was more important than the average income of each household.

Table 4.14 Summary: significant variables among income, prices, physical exercise (PE), caloric intake (CI), fat intake (FI), and community characteristics from the predictions

Variables	pPE	pCI	pFI	pWHR					
				1	2	3	4	5	6
Predicted income	X/X	X/X	X/X	X/X	+**/-	+/-			X/X
Food price		+,-	-						+,-
PE price	-								
No access to PE	-								
Predicted PE				-	X	X	-	-	-
Predicted CI				+/-			+/-		
Predicted FI					+/X			+/X	
Proportion of skilled agricultural, forestry, & fishery workers	-	X	X	-	-	X	-	-	-
Proportion of elementary workers	X	X	X	X	-	X	X	-	X
Average per capita income	X	X	X	-	-	X	-	-	-
Proportion of getting health examination	+	X	X	-	-	-	X	X	-
Proportion of getting education after health exam	-	X	X	X	+	+	X	+	X

Note: Linear term/squared term

X: Not statistically significant at $P<0.05$

+ : Statistically significant positive relation at $P<0.05$

+**: Statistically significant positive relation at P=0.0591

- : Statistically significant negative relation at $P<0.05$

pPE: Prediction of probability of doing physical exercise

pCI: Prediction of energy intake

pFI: Prediction of fat intake

pWHR: Prediction of waist-hip ratio

Model 1: Full model (with energy intake)

Model 2: Full model (with fat intake)

Model 3: Reduced model without dietary intake

Model 4: Reduced model without income (with energy intake)

Model 5: Reduced model without income (with fat intake)

Model 6: Reduced model: with dietary intake replaced by selected food prices

Community characteristics were significant in the predictions. In accord with expectation, as the proportion of heavy labor workers in a community increased, people were less likely to do physical exercise but their WHR decreased. As the proportion of people receiving health examinations increased, people were more likely to do physical exercise and their WHR decreased. Opposite to the expectation, the more people in a community had received education after the health examinations, the less they were likely to exercise and their WHR increased.

In summary, some significant predictors varied across modeling. Based on the modeling in the study, dietary energy intake, physical exercise, and receiving health examinations were important factors for the prevention of central adiposity as measured by WHR. Living in a relatively wealthy place was also related to having a smaller WHR. To help modifying energy intake and induce physical exercise, policies related to prices might be appropriate.

4.4. The magnitude of price effects

In the previous section, prices were noted to have significant effects on the measure of central adiposity. This section answers the question of the magnitude of price effects in terms of dietary intake and the BMI or WHR by using time-series data or cross-sectional. The price elasticity and the magnitude of effects on the WHR were based on price changes between 1998 and 2001. During that three-year period, prices of bananas, soda, coke, sugar, soybean oil, and corn oil decreased.

The price elasticities related to dietary and fat intake and WHR or BMI and their magnitude were based on:

1. Multiplying the elasticity of WHR with respect to energy or fat intake (from Models 1 and 2 in the previous section) by the price elasticity of energy intake with respect to food prices from time-series data.
2. Using the coefficients of Model 6 (the reduced model, with dietary intake replaced by selected food prices related to trade) in the previous section.
3. Using time-series data with the reduced model to obtain the price elasticity related to energy or fat intake and BMI.

At last, the effects of prices on prevalence of overweight and obesity were examined.

4.4.1. The price elasticity for WHR and its magnitude by using cross-sectional and time-series data

4.4.1.1. Price elasticity of cross-sectional data

In the regression of prices on caloric intake (Table 4.7), prices of poultry, soybean oil, and *Soju* were statistically significant at $P<0.05$. The price elasticity for energy consumption was calculated based on the coefficients of that regression (Table 4.15). The calorie elasticities for soybean oil and *Soju* were -0.07239 and -0.10571, respectively, both showing negative signs as expected. However, the price elasticity for energy intake with respect to the price of poultry was positive. It might be that an increase in the poultry price discourages poultry consumption and the subsequent substitution toward more calorie-efficient commodities increases the individual's caloric intake.

In the regression of prices on fat intake (Table. 4.8), prices of bread, instant noodles, and soybean oil were statistically significant at $P<0.05$. Price elasticity for fat intake was calculated based on the coefficients from this regression. The elasticities of fat intake with respect to prices of bread, instant noodles, and soybean oil were -0.18060, -0.65421, and -0.15745, respectively.

Only the price of soybean oil was significant in both analyses. The price elasticity of soybean oil was negative and the absolute value was higher in the prediction with fat intake. That shows fat intake with respect to the soybean oil price was more price-sensitive than energy intake.

4.4.1.2. Price elasticity of time-series data

Time-series data over 31 years from 1975 to 2005 were used to capture the long-term effects of food prices on energy consumption. Due to the multicollinearity between variables, the AR (1) model was used. All variables except the measure of urbanization were log-transformed due to the increasing manner of variance over time, so the coefficients directly show the price elasticity for dietary intake with respect to each food price except those of urbanization measure.

As shown in Table 4.16, overall, the model explained 82.55% of the variance of caloric intake over time. The daily caloric intake was negatively related to the urbanization measure. The price elasticities of rice, vegetable oil, and soda were statistically significant. The elasticities with respect to prices of rice and vegetable oil were positive. One might increase energy intake because, as elevated rice and oil prices discourage their consumption, subsequent substitution toward more calorie-dense food increases.

For fat intake, the model explained 93% of variability. Only the price elasticities of instant noodles and vegetable oil were significant. The absolute value for instant noodles was almost -1 (-0.9558). As shown previously, the price elasticity of vegetables oil was positive. This might occur because, as the increased oil price depresses its consumption, subsequent substitution toward more fat-rich food increases.

4.4.1.3. Price elasticity for waist-hip ratio and its magnitude

The price elasticity for WHR with respect to food prices was calculated by multiplying price elasticities for WHR with respect to energy or fat intake from cross-sectional data by price elasticities for energy or fat intake from time-series data (Table 4.16). The elasticity of WHR with respect to energy and fat intake were 0.72022 and 0.24389, respectively.

The price elasticity of WHR and its magnitude are shown in Table 4.17. In the prediction with energy intake, prices of rice, vegetable oil, and soda were simgnificant. The price of soda shows negative price elasticity and other prices show positive ones. Based on price changes between 1998 and 2001, the WHR changed by 0.015566 due to the price of rice, -0.03604 due to the price of vegetable oil, and 0.011901 due to the price of soda. If one has a hip circumference of 100 cm, the price changes of rice and soda during three years can increase waist circumference by 1.557 cm and 1.190 cm, respectively. The price elasticity of vegetable oil and soda were positive and the price decreased during the three years. The price decrease for vegetable oil correlates with a change in the waist circumference of -3.604 cm.

In the prediction with the intake, only the prices of instant noodles and soda were statistically significant. The price elasticity of instant noodles was -0.23311. The price elasticity of soda was positive here whereas it was negative in the prediction with energy intake. The price changes of instant noodles and soda during the three-year period correlate with a decrease in the waist circumference of 0.168 cm and 5.042 cm, respectively.

Table 4.15 Price elasticity of energy and fat intake from the cross-sectional data

Energy intake		Fat intake	
Food commodity	Elasticity	Food commodity	Elasticity
Rice	-0.06993	Bread	-0.18060*
Wheat	-0.03752	Wheat	0.29154
Instant noodles	0.05839	Instant noodles	-0.65421*
Imported beef	-0.03572	Imported beef	0.03680
Poultry	0.11918*	Poultry	0.17938
Eggs	-0.16512	Pork	0.00876
Bean curd	-0.00070	Bean curd	-0.06718
Delivered milk	-0.02046	Delivered milk	0.04861
Orange juice	-0.06374	Orange juice	0.06723
Apples	-0.00703	Apples	-0.01748
Coke	0.03475	Coke	0.13379
Soybean oil	-0.07239*	Soybean oil	-0.15745*
Soju	-0.10571*	Soju	-0.15587
Pizza	-0.00605	Pizza	-0.01435
Sugar	0.08786	Soda	-0.15457
		Bananas	0.74712
		Citrus fruits	0.08356

***Statistically significant at *P*<0.05**

Table 4.16 Prediction of energy and fat intake: AR (1) model

Variables	Energy			Fat		
	Coefficient (Elasticity)	t-value	P-value	Coefficient (Elasticity)	t-value	P-value
National level						
Urbanization	-0.0114	-2.34	0.0329	0.007104	0.36	0.7250
GNI*	0.0675	2.10	0.0517	0.0934	0.52	0.6096
Food commodity prices (Korean *won*)						
Rice*	0.2374	2.15	0.0476	-0.0308	-0.08	0.9337
Instant noodles*	0.1118	0.88	0.3921	-0.9558	-2.31	0.0327
Domestic beef*	0.0105	0.33	0.7446	0.0360	0.22	0.8308
Pork*	-0.0114	-0.35	0.7340			
Poultry*	-0.0963	-1.51	0.1510	-0.0513	-0.40	0.6905
Vegetable oil*	0.1378	2.42	0.0275	-0.2841	-1.20	0.2469
Soda*	-0.4908	-4.02	0.0010	0.5693	2.48	0.0234
*Soju**	0.0417	0.52	0.6072	0.6781	2.07	0.0534
Sugar*	0.0898	1.35	0.1957			
R^2	0.8255			0.9332		

*Data were log-transformed before testing.

Table 4.17 Price elasticity of waist-hip ratio and magnitude of effects

Price variables	Elasticity	ΔWHR	Δwaist circumference (cm)[1)]
Prediction of energy intake			
Rice	0.17098*	0.015566*	1.557*
Instant noodles	0.08052	0.00058	0.058
Domestic beef	0.00756	0.003079	0.308
Pork	-0.00821	-0.00108	-0.108
Poultry	-0.06936	-0.00178	-0.178
Vegetable oil	0.09925*	-0.03604*	-3.604*
Soda	-0.35349*	0.011901*	1.190*
Soju	0.03003	0.004737	0.474
Sugar	0.06468	-0.01619	-1.691
Prediction of fat intake			
Rice	-0.00751	-0.00068	-0.068
Instant noodles	-0.23311*	-0.00168*	-0.168*
Domestic beef	0.00878	0.003575	0.358
Poultry	-0.01251	-0.00165	-0.165
Vegetable oil	-0.06929	-0.00178	-0.178
Soda	0.138847*	-0.05042*	-5.042*
Soju	0.165383	0.026087	2.609

***Statistically significant at *P*<0.05**

1) Assuming a hip circumference of 100 cm.

4.4.2. The price elasticity for WHR and its magnitude by using the reduced model of cross-sectional data

The price elasticity for the WHR was calculated based on the coefficients of regression of selected food prices on the WHR (the reduced model, Table 4.12). Prices of poultry, corn oil, pizza, and hamburger were statistically significant in the analysis. The price elasticities for poultry, corn oil, pizza, and hamburger were 0.02968, -0.00867, -0.02353, and -0.08700, respectively. The positive value of the price elasticity of poultry might be due to: an increase in the poultry price discouraging poultry consumption and subsequent substitution toward more energy-dense foods increasing the individual's caloric intake (Table 4.17).

The magnitude of changes in the WHR over three years was calculated based on the coefficients from regression of prices on the WHR (Table 4.12). Changes in prices (*won*/100 kcal) of chicken, corn oil, pizza, and hamburger between 1998 and 2001 correlates with changes in the WHR of 0.00076, 0.00170, -0.00048, and -0.00230, respectively. The magnitude of changes was small. For example, the biggest one was -0.00230, which means that, for one with a hip circumference of 100 cm, the price increase between 1998 and 2001 could decrease his or her waist circumference by around 0.23 cm (Table 4.18).

4.4.3. The price elasticity for BMI and its magnitude by using the reduced model of time-series data

To capture the long-term effects of food prices on the BMI using the AR (1) model, food prices, rather than energy or fat intake, were directly used to predict BMI over 31 years from 1975 to 2005. All variables except the measure of urbanization were log-transformed due to the increasing manner of

Table 4.18 The price elasticity for WHR and its magnitude of changes

Food commodity	Elasticity	ΔPrice (Korean Won /100kcal)	ΔWHR	Δ waist circumference (cm)
Rice	-0.01287	6.553584	-0.00115	-0.115
Imported beef	0.00388	8.869858	0.00006	0.006
Pork	0.02025	39.02167	0.00268	0.268
Poultry	0.02968*	5.541135	0.00076*	0.076*
Orange juice	0.01192	1.131843	0.00002	0.002
Bananas	-0.09176	-97.5294	0.03357	3.357
Soybean oil	0.01794	-18.3075	-0.01153	-1.153
Corn oil	-0.00867*	-4.81459	0.00170*	0.170*
Soda	0.02414	-6.95676	-0.00081	-0.081
Soju	-0.01173	26.32719	-0.00181	-0.181
Pizza	-0.02353*	63.35978	-0.00048*	-0.048*
Hamburger	-0.08700*	12.3455	-0.00230*	-0.230*
Sugar	-0.01262	-8.86698	0.00313	0.313

***Statistically significant at *P*<0.05**

Table 4.19 Prediction of BMI: AR (1) model

Variables	Male			Female		
	Coefficient (Elasticity)	t-value	P-value	Coefficient (Elasticity)	t-value	P-value
National level						
Urbanization	-0.000377	-0.04	0.9657	-0.0122	-0.87	0.3921
GNI*	0.0453	0.55	0.5882	0.1784	1.35	0.1934
Food commodity prices (*won*)						
Rice*	0.1738	1.09	0.2894	0.3314	1.22	0.2381
Instant noodles*	0.2862	1.09	0.2900	0.5840	1.26	0.2216
Domestic beef*	0.1883	2.77	0.0117	0.2075	1.85	0.0790
Poultry*	-0.1707	-1.53	0.1412	-0.3416	-1.65	0.1139
Vegetable oil*	0.1855	1.80	0.0870	0.2901	1.57	0.1313
Soju*	-0.1690	-1.00	0.3278	-0.2021	-0.67	0.5123
Soda*	-0.6147	-2.58	0.0178	-0.9849	-2.46	0.0231
R^2	0.8202			0.7676		

*Data were log-transformed before testing.

Table 4.20 The magnitude of effects of prices on the BMI by gender

	Male		Female	
Price variables	ΔBMI	Δkg	ΔBMI	Δkg
Rice	0.431	1.246	0.822	2.100
Instant noodles	0.056	0.162	0.114	0.293
Domestic beef	2.089*	6.036*	2.297	5.879
Poultry	-0.120	-0.346	-0.239	-0.612
Oil	-1.835	-5.304	-2.864	-7.332
Soda	0.564*	1.629*	0.901*	2.308*
Soju	-0.726	-2.099	-0.867	-2.219

***Statistically significant at $P<0.05$**

variance over time. Therefore, the coefficients directly show the price elasticity for BMI with respect to each food price except those of the urbanization measure.

The price elasticity of the BMI for males and females is shown in Table 4.19. As the price of domestic beef increased, the BMI increased. This positive relation might be due to the effect of substitution for domestic beef toward more energy-dense foods. The soda price was negatively related to the BMI. In females, only the price of soda was negatively related to the BMI. The magnitude of effects of prices on BMI in males and females is shown in Table 4.20. In males, the increase in domestic prices changed the BMI by 2.089, which is about 6 kg for a male with a height of 170 cm. In both males and females, the price decrease in soda increased the BMI by 0.564 and 0.901, respectively, which can be about 1.6 kg and 2.3 kg for a man with a height of 170 cm and a female with a height of 160 cm, respectively.

4.4.4. Comparison of results from cross-sectional and time-series data

Among food prices, prices of bananas, soybean oil, corn oil, soda, coke, and sugar decreased during the three years. In addition, the price of imported beef increased less than that of domestic beef. In the prediction of energy intake, the prices of soybean oil in the cross-sectional data and vegetable oils in the time-series data were significant. The sign was negative in the cross-sectional data but positive in the time-series data. For this reason, prices of corn oil and vegetables oil correlated with changes in WHR of 0.0017 and -0.0360, respectively.

In the prediction of fat intake, in both cross-sectional and time-series data, the price elasticity of instant noodles was significant and negative and

Table 4.21 Effects of food prices on the prevalence of overweight and obesity

		After a 10% price decrease			
		Normal	Overweight	Obese	
Before the price change	Normal	3183	1248	206	4637 (44.46)
	Overweight	1057	1626	566	3249 (31.15)
	Obese	176	592	1776	2544 (24.39)
		4416 (42.34)	3466 (33.23)	2548 (24.43)	10430 (100.00)

the absolute value was larger in the time-series data (-0.65421 vs. -0.23311). As shown previously in the energy intake analysis, prices of corn oil in the cross-sectional data and vegetable oil in the time-series data correlated with changes in the WHR by 0.00170 and -0.05042, respectively.

4.4.5. The effects of price on overweight and obesity prevalence

To capture the effects of food prices on the prevalence of overweight and obesity, the prevalence of overweight and obesity was predicted under the assumption that food prices were decreased by 10 percent (Table 4.21). When prices decreased by 10 percent, the prevalence of overweight increased about 2% in the studied population.

CHAPTER 5

CONCLUSION, DISCUSSION, POLICY IMPLICATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

5.1. Summary of findings

The overall aim of this dissertation was to investigate behavioral and policy factors related to obesity. Effects of price, income, community characteristics, dietary intake, and physical activity on WHR were thus investigated in South Koreans. Under the assumption that the effects of trade were mediated through prices and income, the possible linkage between trade liberalization and obesity was also studied. In the three objectives presented in this discussion, the major findings were as follows:

1. Individual, household, and community characteristics associated with central obesity in South Koreans were investigated. The study also showed that prices had an influence not only on dietary intake but also on physical exercise.
2. Effects of income were mediated through dietary intake. Dietary intake, physical exercise, prices, and receiving health examinations were important factors for the prevention of central obesity.
3. Price had a direct impact on obesity. When prices decreased by 10 percent, overweight increased about 2 percent in the studied population.

5.2. Discussion and conclusions

The study found that dietary energy intake and doing physical exercise are significantly associated with central obesity. The positive relation between dietary energy intake and central obesity is as expected. In this study, physical exercise meant doing extra exercise up to the point of becoming out of breath without consideration of duration of time. Participation in physical exercise itself has a preventive effect on central obesity in Korean adults. People who engage in regular exercise might be more likely to have healthy behavior and more concern about their health status.

From the perspective of the consumer demand system, there are four major determinants of household consumption patterns: prices, income, family size, and family composition (Bryant 1990, p.76). The changes in real income alter consumption patterns, and changes in prices of foods themselves and their prices relative to each other also change a household's consumption as well as its real income, which induces income effects. However, changes in prices and income do not change the consumer's preferences. Changes in household size and composition do shift people's preference patterns.

In this study, the variables of household size and composition (proportion of dependents in the household) were included to investigate effects of determinants of household preferences on household consumption in the prediction of dietary intake and physical exercise. Clearly, determinants of household demand alter household consumption: among these four determinants, prices affect doing physical exercise and dietary energy and fat intake, the household composition influences energy intake, and the household size is related to fat intake. However, none of the predicted variables respond to changes in income. In our sample of Korean adults, prices and household size or composition rather than income change consumption and preference patterns of household demand.

Prices of food commodities are directly related to energy and fat intake and prices of and access to health facilities are directly associated with doing physical exercise. These findings indicate that the effects of major predictors on central obesity can be changed by prices and accessibility. In this study, the assumption is that the effects of trade liberalization are only mediated through prices. The agricultural trade policy includes the pricing policy, the producer subsidy equivalents, and the import license, phytosanitary barriers, quotas, and tariffs. All of these influence domestic prices. Reduced prices of soybean oil and Soju increased the energy consumption. On the other hand, energy consumption increased as the price of chicken increased. This positive relation might be due to the effect of substitution for poultry towards more energy-dense foods and partly due to changing relative prices of the various meat products. Over the three years between 1998 and 2001, beef prices increased 45%, pork prices 5.3%, and chicken prices 3.1%. The price of chicken relative to beef dropped by 93.1% during the three-year period. Therefore, one might increase the consumption of poultry regardless of its increased price. The prices of bread, instant noodles, and soybean oil were significantly negatively associated with fat intake. Bread became a substitute for rice, the staple food in Koreans. Instant noodles are frequently used by Koreans as a substitute of meals due to their convenience and low price, especially in low-income families. Due to continuous decrease in the price of soybean oil, it is strongly associated with fat intake in Koreans.

Income was not related to central obesity, but people in the economically better-off community have lower WHR, which indicates that, not an individual level of income, but an average community level of income is an important predictor of central obesity. The community shares many aspects, including environment of factors related to diets, activity, information, and health. Hence, people in rural areas had higher WHR than those in suburban or urban areas. People in rural areas were expected to have more physical activity, but this result suggests the opposite. The result may be due to the lower availability or accessibility of public service facilities or lack of information on obesity. The metropolitan or urban sprawl in South Korea has made for unbalanced development between urban and rural areas. Occupation is related to both physical activity and income levels. By the evidence that the proportion of skilled agricultural, forestry, and fishery workers in the community is negatively related to WHR, occupation in this sample is related to physical work intensity. Education is associated with both income levels and information on health risks. Although levels of education are negatively associated with central obesity, there were no more additional preventive effects after high school graduation. The proportion of people in the community who received health examinations was negatively related to central obesity. After the Unified Health Insurance Act was implemented in 1999, national health insurance policy in South Korea supported regular health examinations. People might have received health examinations at several health clinics including free check-up sites supported by the government. In any case, it is clear that the more people in the community received the benefits of health examinations, the less likely they were to be obese.

Fat intake has a positive linear relation with WHR independently of other risk factors. In contrast to the prediction with energy intake, the prediction with fat intake saw income became significant (though only its squared term) and the probability of physical exercise become insignificant. The relations between central obesity and risk factors vary across the dietary intake variables. Thus, the targeting of interventions should be different based on identified indicators. The differences of results for Models of (1) and (2), i.e., modeling with energy intake and fat intake, might be due to the characteristics of energy and fat intake. Based on the study results, energy intake reflects the income levels and not physical exercise, but fat intake does the opposite.

Income does affect central obesity without any intake variables. That is, the income effects were mediated through the intake variables. Without dietary variables, the explanatory power decreased by about 6-10%. In addition, community variables related to income, such as occupational variables and the average per capita income, became insignificant. However, without the income variable, the explanatory power was almost unchanged. That is, income did not explain central obesity as much as dietary intake. Prices are more strongly associated with central obesity. Without the income variable, the probability of doing physical exercise became significant in the prediction with fat intake, which indicates that, in the presence of fat intake, doing physical exercise is related to income levels in Korean adults.

When selected price variables were included instead of dietary intake, they significantly associated with central obesity. The explanatory power here is similar to the full model. Therefore, prices are more strongly associated with central obesity. Price elasticities for WHR with respect to prices of corn oil, pizza, and hamburger were negative. Transnational food chains have increased their markets in Korea. Pizza and hamburgers became two of the most frequently consumed foods outside the home. In addition, the price of vegetable oil has been decreasing and thus its use and availability has been increasing. Prices of these food commodities were directly associated with central obesity. Price elasticities of poultry and pork (marginally, p=0.0565) were positive. As mentioned earlier, there might be two explanations for these unexpected results: first, there might be an effect of substitution for poultry and pork, due to their price changes, towards more energy-dense food commodities; and second, changes in relative prices of meat products might have effects.

Community characteristics were directly associated with central obesity. The average per capita income of the community is negatively related to central obesity except with the model with individual income. The fact that average community income affects individual obesity shows the importance of underlying causes of overweight and obesity. In addition, the more people in the community receive health examinations, the less they are likely to be obese. These results indicate the need of governmental or community support for prevention of obesity. Communities with low income levels should be more carefully observed. Unexpectedly, as proportion of people who received education after health examinations increased, the WHR increased. It might be that people who receive post-exam education are more likely to be unhealthy, or have diseases. It is true that education after a health exam is recommended for people who have diseases such as diabetes and hypertension in Korea.

The absolute values of elasticities of energy consumption in both cross-sectional and time-series data are mostly less than 0.1 except those for certain food commodities. According to results by Sahn (1988) in Sri Lanka, the price elasticities of demand for calories are much lower than the own-price elasticites although comparisons could not be made in this study due to the lack of information necessary for obtaining own-price elasticities. The price elasticities for soybean oil are significant and negative in both predictions related to energy and fat intake in cross-sectional data. To lower the energy and fat intake by price changes, an increase in the price of soybean oil might be appropriate. There were three statistically significant price variables in prediction of energy intake: poultry, soybean oil, and *Soju*. The absolute values of their price elasticities were similar. However, in the prediction with fat intake, the absolute values for instant noodles were approximately four times and 65 times higher than for those for soybean oil and bread, respectively. The unwillingness of individuals to substitute for instant noodles, as well as high preference for them, shows instant noodles to be the most important food commodity for fat intake.

Price elasticities for energy and fat consumption from time-series data were a little different from those derived from cross-sectional data, though the price variables in analyses were also different due to the availability and collinearity of data. In the prediction with energy intake, prices of rice, vegetable oil, and soda were statistically significant. Price elasticities for rice and vegetable oil were positive, which might due to the effect of substitution towards more energy-dense food due to increases in their prices. In the prediction of fat intake, prices of instant noodles and soda were statistically significant. The price elasticity of soda was positive for fat intake, meaning that the increased price of soda brought effects of substitution toward more fatty foods. The price elasticity of soda for energy intake was negative, but positive values were observed in the fat intake prediction. This means that the increased price of soda correlates with a decrease in people's energy consumption but an increase in fat consumption. As the price of soda increases, people might increase consumption of fatty food rather than healthy food. Absolute values of these elasticities are bigger in the time-series data than in the cross-sectional data. Although the two analyses were based on different datasets, food commodity prices have greater impact on dietary energy and fat intake in the long run. The price elasticity for soybean oil in the cross-sectional data was negative but that of vegetable oil in the time-series data was positive. People decrease the consumption of energy intake when the price of soybean oil increases in the short run, but they increase energy consumption due to the substitution towards more energy-dense food with a the price increase for vegetable oil. The price elasticity of instant noodles was negative in both datasets, and the absolute value was greater in the time-series data. In the long run, the effects of the instant noodle price on fat intake are greater.

The price elasticities for WHR with respect to food commodity prices and their magnitudes were based on combined cross-sectional and time-series data. With the energy intake variables, for the three years between 1998 and 2001, people with waist circumferences of 100 cm, saw their waist circumferences changed by 1.6 cm in correlation with the increased rice price, -3.6 cm with the correlation with the decreased vegetable oil price, and 1.2 cm with correlation with the decreased soda price. With the fat intake variables, people waist circumferences of 100 cm saw their waist circumferences changed by -0.2 cm in correlation with the decreased instant noodle price, and -5.0 cm in correlation with the decreased soda price. Prices of soda and vegetable oil seem to have great changes. As the prices of soda decreased, waist circumferences increased when energy intake was included but decreased when fat intake was included. The total changes of waist circumference due apparently to the changes in the soda price are -3.8 cm. However, based on the reduced model for the time-series, for a male with height of 170 cm, weights changed by 6.0 kg due to the increased domestic beef price and 1.6 kg due apparently to the decreased soda price. For a female with height of 160 cm, weights were changed by 2.3 kg in correlation with the decreased soda price. On the assumption that food commodity prices are directly associated with BMI, soda prices contribute the increase in body weight. Based on the reduced model for the cross-sectional data, people with waist circumferences of 100 cm saw their waist circumferences changed by 0.1 cm due apparently to the increased poultry price, 0.2 cm due to the increased corn oil price, -0.1 due to the increased pizza price, and -0.2 cm due to the increased hamburger price. The changes in absolute values were much lower in the reduced model compared to the results with the full model.

Although the magnitude of changes and the measures are different based on the datasets and modeling, it is clear that changes in prices affect body measures. The assumption of the present study was that the effects of trade liberalization for food commodities are only mediated through prices. The significant price variables are related to the trade in foods or Westernization of food markets, as suggested by the poultry, oil, pizza, hamburger, and soda variables. It is evident that changes in trade affect food prices, changes in food prices influence dietary intake, and dietary intake changes body measures. Based on the reduced model, direct effects of food prices on body measures also exist.

Finally the effects of food prices on the prevalence of overweight and obesity were examined. When it was assumed that prices decreased by 10%, the prevalence of overweight increased about 2% in the studied population.

The prevalence of overweight in South Korean adults has been increasing by 1.6% in males and 2.5% in females per year from 1995 to 2005 (Figure 1.6). Therefore changes in prices might be a significant factor for overweight in South Korea. It is noted that prices of vegetable oil and soft drink were decreased during the study period (Figure 1.2). The increase in overweight prevalence might be related to prices of those.

5.3. Implications for programs and policy

Obesity has become a national health issue in many countries, including South Korea. Results of this study might be helpful for suggesting policies to prevent and reduce central obesity in South Korean adults. In this study, some community variables were significantly associated with central obesity. To discover the vulnerable groups, communities with low average income and low rates of health examination need to be observed. Among them, people with other individual and household characteristics related to central obesity should be identified to help prevent obesity.

Dietary intake and doing physical exercise are major determinants of central obesity. Making environments that encourage people to reduce energy or fat intake and perform more exercise is needed. Based on the study, increasing access to exercise facilities would be helpful. In addition, prices are related to both physical exercise and dietary intake. Since food prices are related to other prices as well as many other economic factors, food price policies to prevent obesity might be difficult to implement. Other options related to access to food commodities might be more appropriate. For example, access to soda could be changed by such government regulations as limiting the numbers of auto-vending machines per area. For other characteristics related to central obesity in Korea, subgroup studies might be necessary before implementing particular policies and programs to prevent central obesity.

5.4. Recommendations for future research

This study included risk factors for obesity at different levels. It identified household-level indicators of dietary intake and physical exercise, two main indicators of central obesity, and described how the determinants of household demand are associated with eating and exercise patterns and preferences. Community characteristics also have an impact on diets, exercise, and measures of central obesity. In addition, a direct association was studied between prices and obesity, which has been very rarely investigated. Prices are directly related to diet and exercise and both directly and indirectly related to central obesity. However, data on prices and the availability of centers of physical exercise were not collected during the surveys. Research collecting data on prices and the availability of both exercise centers and franchised restaurants is needed to investigate effects of trade through prices.

To date, the data of sources used for the present study are the only nationwide health and nutritional survey in South Korea and the subjects were selected based on a stratified random sampling. The surveys were conducted by well-trained field workers and professionals. Their data have been studied and employed by many health professionals and public officials. However, this study found an association between central obesity and the risk of obesity mainly in a cross-sectional setting although the time-series data were used in the last section. It was not possible to determine clearly whether increased dietary intake and lowered probability of doing physical exercise were causes or consequences of obesity. The causal relation between the risk of obesity and predictors should be evaluated in a follow-up in the Korean population. Furthermore, because some data used in the analyses were self-reported by subjects, a potential recall bias might exist. Well-trained interviewers' help may reduce such recall errors. Due to the nature of the data, it was difficult to obtain links between prices and body measures. That should be further investigated in other studies if suitable data are available.

Dietary intake and doing physical exercise are two major determinants of central obesity in South Korean adults. Subgroup studies of people vulnerable to central obesity are needed to modify these behaviors. For adults, modifying such behaviors is not easy. For the cost-effectiveness of programs, studies need to investigate whether direct or indirect changes of indicators are better, i.e., whether direct changes in diet or exercise are better than changes in factors directly associated with them.

5.5. Conclusions

Individual, household, and community characteristics associated with central obesity were identified using statistical analyses of national data collected in South Korea. Community income levels seem to be more important than individual income levels in obesity in Koreans. The study also showed that prices had an influence not only on dietary intake but also on physical exercise, and that dietary energy intake, physical exercise, and receiving health examinations were important factors for the prevention of central obesity. Although it is difficult to detect the association between trade and obesity, there might be relations between trade and obesity under the assumption that its effects are mediated through prices and income in this study. Whether effects of governmental health policy such as receiving health examinations might be preventive against obesity needs to be studied in a follow-up study. Not only individual behavioral factors but also policy factors are important in the reduction and prevention of obesity. To reduce and prevent obesity, it is important to find an appropriate target population. This study would be helpful for the targeting in Koreans.

APPENDIX

Appendix I. Summary of questionnaire

I. Health interview examination

II. Health behavior examination

III. Physical and medical assessment

IV. Nutrition assessment

I. Health interview examination

ITEM	QUESTIONS
Family information	
Education	
Medical insurance	Whether they have it (Yes: insurance types, No: reasons)
Occupation	Whether they work (Yes: job classification)
Self-reported health status	Excellent, good, moderate, bad, very bad
Chronic disease status	
Average monthly payment of medical insurance	
Self-reported socioeconomic status	Very high, high, moderate, low, very low
Average monthly expenditure	
Average monthly income	
Primary health care-center	
Disease history	
Accident experience	
Use of medical service	-Types, duration, frequency, treatments -Reasons for selection (including economic reason -Distance

	-Payment mode: medical insurance coverage -Payment amount : self-payment including transportation fees and extra payments -The effects of these payments on household income -Service satisfaction, other treatments

II. Health interview examination

ITEM	**QUESTIONS**
Self-interest in health	
Smoking	
Drinking	
Drug use	
Obesity and weight control	-Self body-image -Weight changes over 1 year -Weight control experience (exercise, diet, others except exercise)
Exercise	-Daily walking time, regular exercise, average weekly exercising time -Reasons for not doing exercises -Heavy exercise -Average work intensity
Leisure	-Average daily sleeping hours, adequacy of sleeping hours, fatigue -Average weekly working days -Average daily working hours -Adequacy of resting time -Leisure time use
Stress	-Degree of stress

	-Reasons -Suicide attempt
Extra preventive behaviors	-Experience of medical or physical examinations -Payment method for medical or physical examinations -Health education experience after examinations -Usefulness of the examinations -Cancer examinations -Experience of blood pressure measures (except by automatic machines) -Health information source
Safety behaviors	-Car driving experience, seat belt use, driving after alcohol use within last 1 year, use of child's car seat
Respiratory diseases	
Bone diseases	
Women's diseases	

III. Physical and medical assessment

ITEM	QUESTIONS
Physical assessment	Weight (.00), height(.00), waist circumference (.0), hip circumference (.0), head circumference (.0), chest circumference (.0)
Biochemical assessments	Blood pressure, blood HDL cholesterol, blood triglyceride, blood cholesterol, urinary protein, urinary glucose, hemoglobin, hematocrit, red blood cell count, lung function (FVC, FEV_1)
Extra questions	-Family history of hypertension, cardiovascular diseases, liver diseases, diabetes -Current use of medicine for hypertension, diabetes, liver diseases, renal diseases, anemia -Vitamin or mineral supplement use, vitamin C supplement use -Pregnancy

IV. Nutrition assessment

ITEM	QUESTIONS
Food frequency questionnaire	
Dietary behaviors	-Did you have breakfast, lunch, or dinner over the last 2 days? -If you did not, what is the major reason? (1. overslept 2. loss of appetite 3. indigestion 4. snacks 5. weight control 6. economic 7. time 8. habit) -Frequency of having snacks -Major kinds of snacks -How many times do you eat out? -When you eat out, how salty is the food? -Consumption frequency of fried food -Use of vitamin, mineral, nutritional, or herbal supplements -Motivation for supplement uses -Women: age at menarche, age at menopause, pregnancy, lactation
24-hr recall	

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